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HARDY APPLE ROOTSTOCK

INVESTIGATIONS

IN

CENTRAL ALBERTA.

Agriculture 1954

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ABSTRACT

Eight crabapple varieties were used as a source of seed for apple rootstocks which were budded to two apple varieties. The resulting unions were the subject of an intensive study to determine the superiority or inferiority of the rootstocks and to compare the methods of evaluating the compatibility of stock/scion combinations.

The following methods of evaluating unions were compared: vigour of scion variety, strength-at-union, water conductivity through the union, macroscopic evaluation of the union, microscopic evaluation of sections from the union, type of break at the union, premature defoliation and "take" of buds.

Vigour as measured by the scion diameter, strength-at-union and water conductivity through the union were the only methods of evaluation considered reliable. Evaluation of the unions by these methods indicated that no rootstock line was superior or inferior to the other lines for both scion varieties.

Hardiness studies indicated a relative lack of hardiness in one rootstock line which was produced from open-pollinated seed of a number of varieties of unknown hardiness. All other lines came from varieties known to be hardy and no winter injury was evident in these lines.

THE UNIVERSITY OF ALBERTA

HARDY APPLE ROOTSTOCK INVESTIGATIONS IN CENTRAL ALBERTA

A DISSERTATION

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

FACULTY OF AGRICULTURE

DEPARTMENT OF PLANT SCIENCE

by

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EDMONTON, ALBERTA

APRIL 1954

ACKNOWLEDGEMENTS

The investigations described in this thesis were carried out under the direction of Dr.R.J.Hilton, Professor of Horticulture to whom the writer wishes to acknowledge his indebtedness for advice and assistance throughout the work.

The writer also wishes to thank, Dr.J.H. Whyte of the Department of Botany for placing at his disposal facilities for certain tests, the Superintendent of the Experimental Station, Morden, Manitoba and the Superintendent of the Provincial Horticultural Station, Brooks, Alberta for supplying plant material for the tests, Dr.Saul Zalik of the Department of Plant Science for advice concerning statistical analysis and technicians of the Department of Plant Science who assisted with many phases of the study.

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INTRODUCTION

Deciduous fruit trees are usually propagated vegetatively because they are heterozygous and do not grow true to variety from seed. Certain kinds can be propagated by root cuttings, stem cuttings or layers but plants of the genus Malus do not respond readily to these treatments. It is therefore necessary to resort to grafting.

Grafting may be defined as the transfer of a bud bearing scion to a stock upon which the scion may develop. The stock may be referred to as the rootstock and it may be a piece of root, a whole root, a young plant or a tree of greater age.

The choice of rootstock is important. All combinations of stock and scion are not harmonious and in some cases there is a discordant association which has been referred to as "uncongeniality", "lack of graft affinity" and "incompatibility". The term "incompatibility" is most widely accepted and will therefore be used in preference to the others. Incompatibility affects the vigour and life of trees. A stock/scion combination that is entirely incompatible will fail completely to make a functional union.

Other factors which must be considered in the

selection of a rootstock include the inherent variability of seedling stocks, disease resistance and hardiness.

Variability of apple stocks has long been the subject of research in established fruit growing areas of the world. The problem of variability has been overcome by the use of clonal stocks or apomictic seedling stocks. The compatibility of many stock/scion combinations is well known and the performance of many combinations wherein uniform clonally propagated rootstocks are used has been the subject of many empirical studies.

The hardiness of rootstock source material in tree fruits has not received much attention because all important commercial fruit growing areas are not in the most severe climatic regions. Thus it so happens that the apple rootstocks which have received the most research attention are not hardy enough for Alberta conditions.

Disease resistance is not considered of major importance in Alberta as yet, but it is believed that rootstocks developed from varieties grown here will exhibit some of the disease resistance which the varieties possess. Further the most important tree fruit diseases in the Canadian prairies are much more likely to attack older than young plants, hence the young trees in the rootstock nursery row are rarely

subject to damage from disease infection.

Seedlings of hardy crabapples are widely used for rootstock purposes throughout the prairie provinces. An evaluation of the uniformity and compatibility to be expected from these rootstocks is of practical importance to the nurseryman and the fruit grower, and represents an original field for research. The project reported herein was undertaken for the purpose of comparing the uniformity and compatibility of seedling rootstocks commonly used in Alberta.

LITERATURE REVIEW

The Apple Rootstock Situation

The East Malling Research Station in England has collected and evaluated a number of clonal rootstocks which have various characteristics and well defined influences upon scion varieties (1). These rootstocks have not proved hardy in Ottawa (3) and Manitoba (38) but are hardy in Nova Scotia (20), Southern Ontario (36) and British Columbia (21). Since these rootstocks are not hardy enough for Ottawa Valley and Southern Manitoba conditions they are not worthy of trial in Alberta where winter conditions are more severe.

Davis et al (11) report that certain clonal rootstocks being produced at the Central Experimental Station, Ottawa are hardy under their conditions. One of these rootstocks, Malus robusta #5 is being tested in Alberta. If this rootstock is hardy and compatible with varieties being grown in Alberta it will be valuable for establishing uniform orchards for research work. However the increased cost of propagating clonal stocks, unless they have a dwarfing or other valuable influence on the scion, will not make them popular for general nursery work.

Kerr (19) states that nurserymen advertise apple and crabapple varieties on Malus baccata seedlings. He claims that this does not mean much because these stocks are usually variable. He suggests that seedlings of Columbia and Bedford should be used as they are uniformly vigorous,hardy and resistant to fireblight, and are easily grown.

Numerous apple rootstocks are mentioned by Argles (2) but generally they are known to be of little value for Alberta conditions. Argles notes that few cases of incompatibility in Malus have been reported but this is not surprising as a limited number of species have been used. Malus pumila is widely used in Europe while Malus baccata and Malus ioensis have been used extensively in the United States where particularly hardy apple rootstocks are required.

Possible Causes of Incompatibility

A. Botanical Relationship.

It is a recognized practice to graft pear on quince in England and in some cases no signs of incompatibility have been observed (1). These fruits belong to different genera, Pyrus and Cydonia respectively. Michurin(22) reports the presence of an apparently successful union between lemon and pear.

Argles (2) also cites one report where two apple varieties are said to have been successfully grafted on pear stocks.

On the other hand numerous workers report incompatibility between species within the same genus especially the genus Prunus (1, 15). Tukey and Brase (34), and Chang (8) note that a diploid apple rootstock was found to be more compatible with a triploid variety than with some diploid varieties.

Botanical relationship and also chromosome number do not appear to be completely reliable guides to compatibility of stock and scion. Even if botanical relationship was a guide,a great many modern varieties are hybrids of two or more species and the problem of estimating stock/scion compatibility and the general performance of grafted combinations would still be complex.

B. Growth Characteristics.

Many workers have suggested that a similarity in growth characteristics of stock and scion determines their compatibility especially in the case of Michurin's (22) pear-lemon combination. However, Bradford and Sitton (6) cite cases of reported incompatibility wherein the stock and scion show little or no difference in growth characteristics.

More recently, Roberts (29) states that time of wood maturity is the only tangible factor which can be used to predict the success of a stock/scion combination within a species. He asks, "is this morphology or physiology ?" Herrero (16) observed nine major histological characteristics of stock and scion which were not correlated with incompatibility.

C. Biochemical and Physiological Differences.

The failure of certain chemical compounds to pass through the union is often described as the reason for incompatibility. Argles (2) reviewed the literature dealing with this aspect and he suggests that further investigation is warranted.

Acquired precipitin reactions were studied by Whitaker and Chester (40). They found most positive reactions were due to the precipitation of calcium oxalate. The presence of this precipitate nullified the test.

Moss and Herrero (24) and Chang (8) found abnormal starch accumulations above the union in incompatible combinations. Haas and Halma (14) in earlier work noted that starch accumulation need not be the cause of incompatibility but may be the result of the girdling effect of an incompatible union.

Graft unions do not prevent the downward movement of starch, fats or nitrogenous compounds in

certain dwarf combinations, according to Colby (9). He noted that the upward movement of starch was retarded in the spring but this he associated with suberization of roots and a resultant decrease in water uptake. It should be noted that Colby may not have been dealing with incompatible combinations as the dwarfing effect according to Argles (2) does not necessarily indicate incompatibility.

Moss and Herrero (24) express the opinion that future studies concerning the cause of stock/scion incompatibility should be in the biochemical field. It may be that techniques now used in the study of viruses in plants may be valuable tools in such investigations.

Manifestations of Incompatibility

A reliable measure of incompatibility between stock and scion combinations is essential when such combinations are being studied to determine their value as rootstocks.

Argles (2) in 1937 reviewed the literature on stock/scion incompatibility in tree fruits. He notes that the following conditions appear to be symptomatic of inherent incompatibility and of no other disordered state:

1. Presence of isolated masses or sheets of

parenchymatous tissues or bark at the line of union.

2. Breaking of trees at the line of union particularly when the break is clean.

Other conditions which may be symptomatic of incompatibility but are possibly due to other factors are:

1. A relatively small proportion of successful unions formed.

2. Complete failure to form a union.

3. Premature decline and death of trees.

4. Ill health of trees.

5. Swellings at the union.

It is apparent that a measure of incompatibility should be based upon one or another of the conditions which are symptomatic of inherent incompatibility, excluding where possible the likelihood of external factors being responsible.

Methods of Evaluating Stock-Scion Combinations

A. Parenchymatous Tissue or Bark at the Line of Union.

In a microscopic study of structural defects of the graft union, Proebsting (25) found that where incompatibility was manifested there was some structural defect or defects at the line of union. He reports that defects vary greatly between combinations of stock and scion. It is significant that he found the variation

within a combination to be less pronounced than that between combinations.

The most common type of structural defect according to Proebsting is that involving the deposition of wood parenchyma by the cambium at the line of union. The parenchyma varied from isolated patches with vessels around them connecting stock and scion, to a continuous sheet covering the whole area of contact. Proebsting contends that in either case the union is mechanically weak and that in pronounced cases the tree will break off at the union when its surface offers enough resistance to wind.

Unions of recently budded incompatible combinations were shown by Chang (8) to contain bark and parenchyma at the point of union. These tissues became relatively more pronounced as the age of the unions increased.

Hilton (17) had similar results using pear on quince. The three combinations being studied could be assigned to classes which corresponded to their known degree of compatibility. Hilton also reported the presence of thick walled cells at the line of union in incompatible combinations.

Distortion of vascular tissues at the line of union was also taken as a measure of incompatibility by Chang (8).

Herrero (16) found no correlation between certain histological features of stock and scion, and compatibility but he reports that undifferentiated tissues were present at the line of union in incompatible combinations. He also notes that within a plum combination a wide variation in this condition was not unusual.

B. Breaking Tests and Nature of Fracture

The presence of undifferentiated tissue at the line of union causes a disruption in vascular continuity. It can be assumed that such lack of continuity will weaken the union. It is on this basis that numerous workers have attempted to correlate the strength of the union and compatibility.

Chang (8) found that the force required to break unions known to be compatible was much greater than that required to break incompatible unions. He noted that incompatible unions broke cleanly, somewhat like a ball being removed from a socket, while compatible unions when broken left jagged ends.

There were some anomalies in Chang's results however, and Hilton (17) pointed out that Chang had not used the Modulus of Section for a cylindrical beam to calculate the Modulus of Rupture. When Chang's data was re-calculated with the correct formula the anomalies were not present.

Hilton used an apparatus similar to Chang's

but he dealt with unions on frameworked trees. The results indicated that the degree of compatibility could not be accurately measured by this method.

Suit (32) in earlier investigations had found breaking strength a good measure of compatibility in graft unions.

A recent paper by Randhawa et al (26) contains data that indicates pear trees which had obvious anthocyanin pigment in their leaves were mechanically weaker at the union than the plants which bore normal green foliage.

An exception to the above is reported by Moss and Herrero (24). They note that mechanically weak unions are not always associated with poor tree performance.

C. Macroscopic Evaluation of Unions

It is usually considered that enlarged unions and unions showing signs of bark discontinuity indicate incompatibility between stock and scion.

Chang (8) says that bark discontinuity is a symptom of incompatibility and Hilton (17) found that this was true in most cases, but crevices which appeared in bark of compatible 1 and 2 year old combinations disappeared later. Thus bark discontinuity is not always associated with incompatibility and this is confirmed by Randhawa and Upshall (27). They do claim that swelling at the union is a normal expression of incompatibility however.

D. Percentage "Take"

The number of unions which form in a particular combination may suggest the degree of compatibility. Grafting is so affected by environmental conditions, such as temperature and humidity as well as the skill of the grafter that care must be taken in assessing compatibility on the basis of the number of unions formed.

Tydeman (35) reports a positive correlation between "take" and compatibility in certain pome fruits. Amos et al (1) found that "take" was a fairly good indication of compatibility in some cases.

The wide divergence of results obtained by Chang (8) leads him to conclude that "take" was not a reliable guide to compatibility. Hilton (17) observes that percent "take" may be taken as an indication of compatibility, particularly in the case of frameworked trees.

E. Water Conductivity Tests

It is reasonable to assume that if relatively undifferentiated parenchymatous tissue displaces normal xylem at the line of union the flow of water through the union should be retarded. This was the assumption that Chang (8) used when he drew water through unions. He reported a correlation between compatibility and the passage of water through a union in a specified period at a specified reduced pressure inducement. Randhawa

and Upshall (27) using similar apparatus reached the same conclusion.

F. Passage of Dye Through the Union

Dyes offer a means of studying conductivity through the union. Hilton (17) observed that the passage of dye through the union of incompatible combinations was much less than that through compatible combinations. The time taken for a dye to pass through the union was less for compatible than for incompatible unions according to Chang (8).

G. Starch Accumulation at Union

This aspect was discussed under possible causes of incompatibility. Quantitative measures of starch above the union may be worthwhile.

H. Shoot Growth or Vigour

It may be argued that a compatible combination should produce more top growth than an incompatible one. Chang (8) observed that scions grew faster at first on incompatible rootstocks but declined rapidly after July. Shoot length and compatibility are correlated according to Tydeman (35). Hilton (17) found that while growth of scions in pears is an indication of compatibility the growth of maiden plum trees is not always a criterion but he also states that certain plum rootstocks are superior because they produce larger maiden trees.

Incompatible plum and pear/quince combinations did not affect the early shoot growth according to Herrero (16) but in peach/plum combinations less shoot growth was present in incompatible combinations. Pear/quince combinations used by Tydeman(35) on the other hand showed a very pronounced reduction in shoot growth where the combination was known to be incompatible. Shaw and Southwick (30) report that top growth appears to be a measure of compatibility in apples.

Roberts (28) notes that nursery trees tend to maintain relative differences in size that result from the first season's environment.

In one year old trees, the amount of lateral branching often complicates the use of shoot growth as a measure of vigour. Literature dealing with this aspect was reviewed.

Trunk circumference was found by Collison and Harlan (10) and Wilcox (41) to be a reliable index of tree size. Bradford and Joley (5) reported that weight was the best criterion of growth but found it was difficult to measure on living trees. They devised a scale for converting shoot length to weight, but the scale was only applicable to individual varieties.

Sitton and Dodge (31) working with pecans found a correlation between cross-sectional area and top growth. Using apple grafts Waltman (39) observed a high

correlation between height and diameter of grafted trees and Cannon (7) made a similar observation with clonal quince rootstocks.

Most workers would agree that weight is the most reliable measure of growth. It is however difficult to make this measurement. Diameter, circumference or cross-sectional area may also be useful for this purpose, the first two listed being relatively the same measurement.

I Colouration of Foliage

Upshall and Dickson (37) report that early colouration of leaves on pear trees in the nursery is associated with incompatibility between stock and scions in later years. This aspect is worth investigating in apples.

EXPERIMENTAL PROCEDURE

Materials

Seed of eight crabapple varieties was procured from the Experimental Station, Morden, Manitoba in the fall of 1949. The varieties of crabapples were as follows with their parentage in brackets:

Alberta (*Malus baccata* (L.) Borkh. x Haas)
Bedford (open-pollinated seedling of Cluster)
Columbia (*Malus baccata* (L.) Borkh. x Broad Green)
Dolgo (from Russia, parentage unknown)
Elsa (*Malus baccata* (L.) Borkh. x Yellow Transparent)
Osman (*Malus baccata* (L.) Borkh. x Osimoe)
Ornamental (a mixture of seed from ornamental varieties which have *Malus pumila* Mill. var. *niedzwetzkyana* (Dieck) Schneid. as an ancestor)
Beauty (open-pollinated seedling of Cherry)

These varieties were selected because they are among the hardiest and most widely grown varieties in Alberta and are the usual source of seed for rootstocks. Columbia is the variety used as a seed source in the majority of cases.

The scion varieties for the investigation

were Rescue (an early-maturing seedling of Blushed Calville) and Haralson (a seedling of Malinda). Rescue is called an apple-crab and originated at the Experimental Station, Scott, Saskatchewan. Haralson (a University of Minnesota introduction) is a large late-keeping apple variety. Each appears to be representative of its class and both are widely recommended in Alberta.

Throughout this report the rootstock lines usually will be referred to by the name of the variety from which the seedling stock was grown. It must be borne in mind, however, that these progeny are the result of uncontrolled pollinations, and therefore subject to the degree of variability usually associated with Malus seedlings of this kind.

Methods.

A. Production of Seedlings.

During the fall of 1949 some of the seed of each line was field planted. The remainder of the seed was planted in the spring of 1950 after 30 days stratification in moist peat at 34°F. The fall planted seed germinated poorly but the spring planted seed germinated well.

Plant growth was poor in 1950 and no plants were suitable for budding that season.

In May 1951 the seedlings were transplanted from their original location to four rows approximately

250 feet long and three feet apart. Plants were spaced two inches apart in the rows. Each row was divided in four parts. A line was assigned at random to each division of the two outside rows, and to each division of the two inside rows. That is, each line was divided into two groups so that one group would be in an inside row and one in an outside row. The division was made to compensate for environmental factors as true replication was not feasible.

Fertilizer (ammonium phosphate, 11-48-0 analysis) was applied to each side of each row during 1952 and 1953. Moisture was not limiting at any time during this two year period.

B. Budding.

In early August 1951 the scion varieties Rescue and Haralson were budded by the shield method onto the rootstock lines. Fifty buds of each variety were placed on each line.

During 1952 it was evident that the "take" was extremely poor and budding was repeated in late July and early August 1952 but this time units of one hundred buds of each scion variety were used on each rootstock line. Fifty buds were put on each rootstock line in each of the two locations of the line. That is, each group of 50 buds was inserted at different dates in different locations. The lines were budded at random at each date.

Rescue budwood was obtained from trees in the University orchard as it was required. Haralson budwood was obtained from the Experimental Station, Morden, Manitoba and Provincial Horticultural Station, Brooks, Alberta.

The budded plants which developed in 1952 were removed in October 1952 and were used for preliminary studies.

In June 1953 tops were cut back to the inserted buds with a very short snag of the seedling tissue left above the bud.

C. Field Observations.

In 1951 and 1952 mortality of seedlings was observed but no accurate record was made. Percentage mortality was estimated.

"Take" of buds was recorded in 1953 and is reported in Appendix I. In this report the two dates of budding are taken as replicates as they represent two locations in the plot.

Observations were made on normal autumn defoliation of seedling stocks in 1952, and of scion varieties in 1953.

D. Handling of Stock-Scion combinations.

In October 1953 fifty plants of each of the stock/scion combinations were dug. In some Haralson combinations 50 plants were not available and all

available plants were removed. Half of the plants of each combination were taken from each location in the rows where the number of plants allowed this procedure.

Forty plants were used for later studies so that an equal number of each combination would be represented in each test.

The plants were labelled as to combination and their roots placed in moist peat under out-of-doors conditions.

E. Measurements of Stock and Scion.

The plants were taken indoors for measuring on October 30. The length of top growth was measured in centimetres. Lateral branches were also measured.

Roots were removed except for 6cm. below the union and the top was removed except for the 6cm. immediately above the union. Each combination was labelled with a designation that indicated both the combination and the particular union.

The diameter of each combination was measured with calipers at the following places:

1 cm. above the union.

1 cm, below the union.

5 cm. above the union.

at the union.

As measurements were completed the unions were placed in polyethylene bags with a sheet of moist

paper towel in each bag and then held in a cool storage chamber until they were used for various tests.

F. Water Conductivity Measurements.

The theory underlying the use of these measurements has been discussed in the literature review. Apparatus similar to that used by Chang(8) was assembled. The apparatus enables the operator to handle six unions at one time. The apparatus is shown in Fig.1. and is described in detail later.

The scion and stock were cut so that 5cm. of each remained above and below the union. Each end was pared with a sharp knife to ensure that sawdust plugging of vessels would not occur.

The stock end was attached to a 50 ml. burette by means of soft rubber tubing and a clamp was placed on the stock-rubber union to ensure an air tight seal.

The scion end was inserted into pressure tubing which in turn was connected with a vacuum pump and manometer. The scion-rubber union was also clamped.

Preliminary studies indicated that the stub of the union and any cut surfaces of the combination should be waxed. A semi-plastic wax used in the cheese industry was applied to the surfaces requiring treatment.

When the unions were in place and waxed, tap water at room temperature was poured into the burettes.

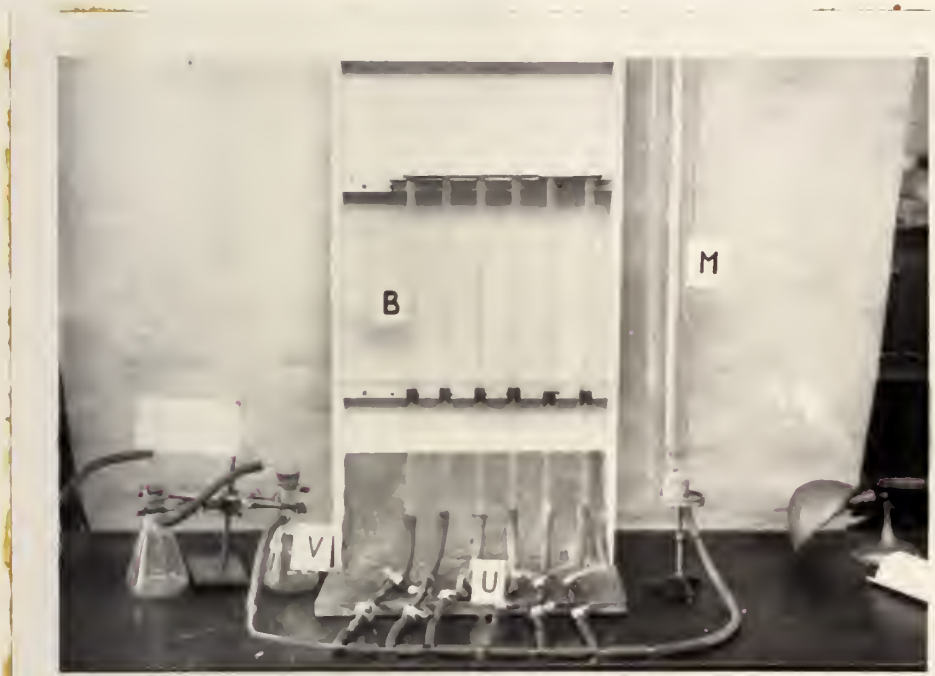


Fig. 1. Water conductivity apparatus.

V - vacuum flasks.

U - unions

M - manometer

B - burettes.

The tubing at the end of each burette was then pinched repeatedly to expel air. Water was again added to the burettes until they were full.

A uniform reduced pressure was maintained in the system by using a Pressovac 4 Pump which was connected to the unions through a valve system and vacuum flasks. Pressure tubing was used throughout this part of the system.

The valve system consisted of two coarse adjustment valves and a needle valve. The needle valve enabled the operator to maintain a constant pressure. One of the coarse adjustment valves was kept closed except when it was desired to reduce pressure at the end of a test. This allowed the needle valve and the other coarse adjustment valve to be left in their original positions for a number of tests if atmospheric pressure did not vary appreciably.

The vacuum flasks provide a reservoir of air which prevents violent fluctuations in the pressure. One vacuum flask also traps water before it reaches the pump.

A simple mercury manometer was used to measure the reduced pressure in the system. It consisted of a glass tube one end of which was immersed in a bowl of mercury. The other end was connected to the system by pressure tubing.

The bowl of mercury was placed on an

adjustable stand. This allowed the operator to adjust the mercury level to zero on the scale when the proper vacuum was obtained.

The valve system was opened before the vacuum pump was started and then it was closed until the manometer reading was 620 mm. . Throughout the conductivity tests reported here the pressure was maintained at this level. i.e. 620 mm. of Hg.

Preliminary studies made in 1952 indicated that a uniform flow of water was obtained after 5 minutes and this rate of flow did not alter appreciably in any 10 minute period in the following 30 minutes. Therefore burettes were read 5 minutes after the vacuum pump was started and the pressure had reached 620 mm.; and read again 10 minutes later. The difference in the readings was called the "actual" amount of water passing the union. The actual conductivity was reduced to "ml. of water passing the union per square centimetre of cross-sectional area per 10 minutes" by dividing it by the cross-sectional area of the scion 5cm. from the union.

The cross-sectional area at 5cm, from the union was considered the minimum area of conductive tissues in the combination except where disruption occured at the line of union.

The possibility that the area at 5cm. was not the best area with which to calculate the water conductivity

per unit area was considered. The following formula was used to calculate water conductivity on the basis of the union diameter:

$$\frac{\text{Actual Water Conductivity}}{\left(\frac{\text{scion diameter at 1cm.} + \text{stock diameter}}{4}\right)^2 \times \pi}$$

G. Macroscopic Evaluation.

All unions were scored on a basis of 1 to 10. A score of 10 indicated a combination which was apparently perfectly compatible. Unions were devaluated according to the amount of swelling and bark discontinuity.

H. Microscopic Evaluation.

Half of the unions used in the conductivity tests were taken at random for microscopic evaluation. Wax which remained from the conductivity study was removed by dipping the unions in hot water and then wiping them with paper towels.

Approximately 2cm. of the bud union region was removed from all selected unions for each combination and these were placed in Farmer's Fixative after being labelled with indelible pencil to indicate the combination and number of the union.

After 48 hours the unions were transferred from the Farmer's Fixative to an alcohol-glycerol (50-50) softening solution. After 5 days in this solution the

unions were sectioned to 20 microns with an MSE sliding microtome. Sections were cut at the base of the scion at a point where bud scales of the original bud had abscised.

The sectioning operation was facilitated by placing the material in 95% alcohol for 24 hours prior to sectioning rather than sectioning it directly from the glycerin-alcohol solution. Better sections also were obtained if the microtome blade was kept wet with glycerin and water, and if the blade was kept cold by frequent cooling in the refrigerator.

Sections were stained with Safranin and Delafield's Haematoxylin according to the procedure outlined by Johansen (18). The sections were then dehydrated with alcohol and xylol and mounted in Canada Balsam.

After drying for one month the sections were scored on the following basis:

1. Stock and scion almost separate units. Divided by cork or space.
2. Stock and scion almost separate units. Divided by cork and parenchyma.
3. Stock and scion almost separate units. Divided by parenchyma.
4. Some union of wood but predominantly callus, cork or parenchyma.
5. Parenchyma prominent, some cork.
6. Parenchyma prominent, or parenchyma and distorted wood.

7. Isolated patches of parenchyma or cork, or mainly distorted wood.
8. A little parenchyma in part of union or slight distortion of wood.
9. Wood tissues of stock and scion merge and line of union only distinguishable by presence of wood from bud shield.
10. Line of union indistinguishable, except for original bud shield.

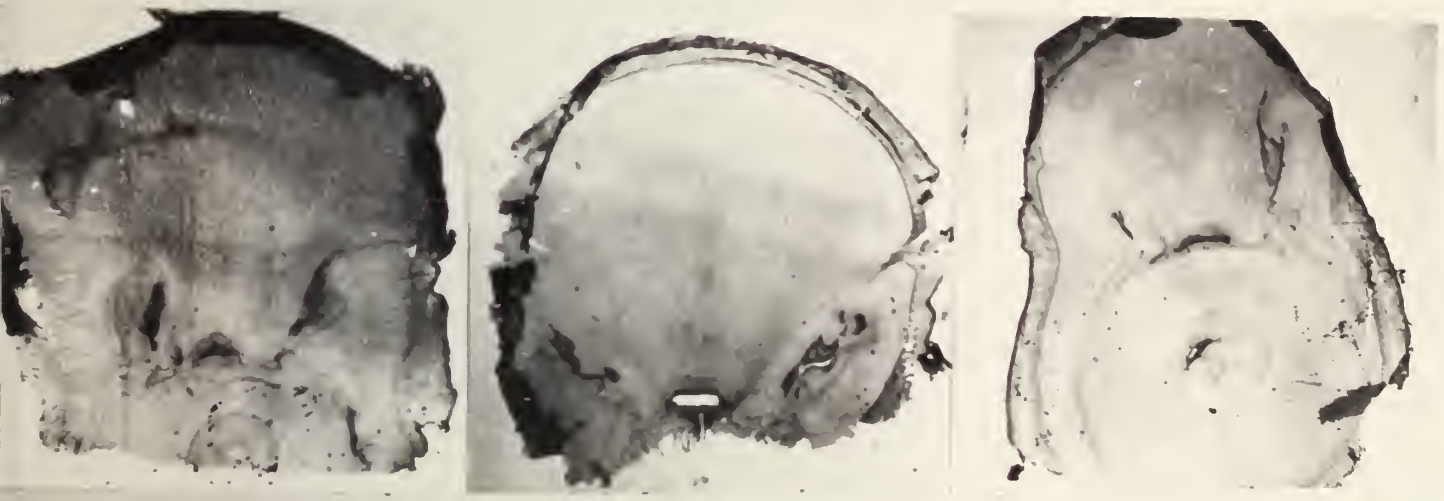
Where the two sides of the union differed each side was evaluated and the mean of the two values was recorded.

A Bausch and Lomb dissecting microscope was used for evaluation studies. Magnification of 15X was found to be satisfactory.

Fig.2 illustrates the types of unions as they were evaluated. Colour differences not visible in the black and white photographs made evaluation easier than the photographs would indicate.

Detailed microscopic studies of the various tissues were made before evaluation was attempted. It was observed that dark red tissues either were dead wood or bark. Ordinary periderm was dark blue. Callus tissue appeared as dark blue masses of cells and these tissues as well as parenchyma and wood could be easily distinguished under the dissecting microscope.

2 3 4



5 6 7

8 9

FIG. 2. Sections of bud unions. The numeral beneath each union indicates the compatibility rating for that type of union. X 4.5.

I. Breaking Strength Tests.

This test was discussed in the literature review. Various kinds of apparatus have been used for the test (8,17,26,32). In all cases the union is broken and the force required to break it is measured. The union is either suspended as a beam or the scion portion is used as a cantilever.

A preliminary study was made in 1952 using the union as a beam and applying the force with a lever. However the stock and scion do not form a uniform cylindrical beam and there was a tendency for the union to rotate on the knife edges, consequently the unions were not being broken in the same direction each time. It was decided that apparatus similar to that employed by Hilton (17) would be more satisfactory.

The apparatus used is shown in Fig.3. The stock portion of the combination is fixed in a vise so that the budded side faces away from the operator. A hardwood arm approximately 55cm. long is firmly fixed to the scion by means of ring bolts which are fitted with wing nuts. The bolts are set into the wooden lever so that when the wing nuts are tightened the scion is drawn against the lever.

At a point 50 cm. from the union a hole was drilled in the lever. At this point pressure was applied

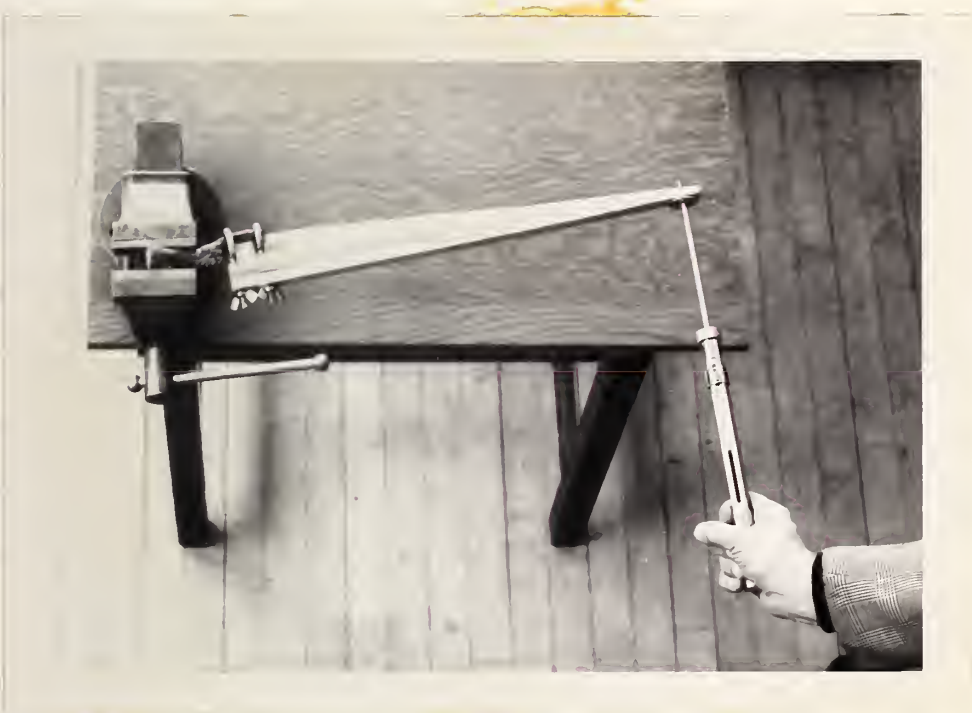


Fig. 3. Breaking strength apparatus.

in the horizontal plane with a Ballauf Fruit Pressure Tester until the union failed. The force applied was recorded.

In some cases it was evident that the unions were too weak or too small to give a reading on the dynamometer if a lever 50 cm. long was used. For these unions the force was applied 25 cm. from the union and the reading was adjusted before entering it in the records.

Of the unions that were used in the water conductivity test one half were subjected to the breaking strength test.

As unions were broken they were evaluated as to whether the breaks were clean (C) or tearing (T), intermediate classes were CT or TC depending on the type of break. Fig. 4 illustrates the differences observed.

Breaks were usually elliptical in shape and the long axis of the ellipse was measured but this measurement is not reported since it was found to be unsuited to data evaluation procedures.

The Bending Moment (BM) was calculated for the observed force applied(f). The formula used was BM = fx50. The BM is in units of cm. pounds.

The Modulus of Rupture was calculated using the modulus of Section for a cylindrical rod (23). i.e. $\frac{\pi d^3}{32}$ where d is the diameter of the rod.The diameter of the union was taken as the diameter of the rod.

Modulus of Rupture (MR) is therefore:

$$\frac{BM}{\text{Modulus of Section}} = \frac{32\ BM}{\pi d^3} = \frac{10.86\ BM}{d^3}$$

Fig. 4. Broken unions.

Left. Torn break (T)

Right. Clean break (C)

According to Boyd (4), while the modulus of rupture does not give the actual unit stress in the outer fibres, it makes it possible to compare stresses in similar sections.

The modulus of rupture in this study is reported in pounds per square centimetre of cross sectional area.

Some of the moduli of rupture were calculated on the assumption that the rod was elliptical. It was evident that this was not a true picture of the cylindrical rod although the break was usually elliptical in shape. It can be seen that a diagonal break in a cylindrical rod should not be treated the same as a break of similar section in a truly elliptical rod. These calculations are not reported.

General Methods of Analyzing the Data

Correlation studies were made to determine whether or not relationships existed between various factors. In some cases the correlation coefficients were calculated for the whole population but in others only for one or two combinations. If no trend in correlation was observed when two or three combinations were used that particular phase of the study was discontinued.

Certain partial correlation coefficients were calculated to remove the effect of stock diameter.

Analyses of variance were carried out on data from all tests.

Analysis of covariance was applied to the scion diameter data to remove the effect of stock diameter.

Data concerning the type of break at the unions was scrutinized and compared to the other data.

The results of the analyses will be reported under Results and Discussion. In many cases it has been found convenient to use symbols to indicate the measurement being discussed.

e.g. shoot length - s.
correlation of scion diameter at 5 cm. (i) and stock diameter at 1 cm. (d) - r_{id}

All analyses were based on methods outlined by Goulden (13).

ORIGINAL DATA IN APPENDIX TABLES.

The following data are reported in appendix tables:-

Data for:	Appendix	Tables
"Take" of buds	I	
Shoot length	II	1 to 16
(lateral shoot growth is summated and reported in brackets)	III	1 to 16
Scion diameter at 1 cm.	II	1 to 16
	III	1 to 16
Scion diameter at 5 cm.	II	1 to 16
	III	1 to 16
Stock diameter at 1 cm.	II	1 to 16
	III	1 to 16
Union diameter	II	1 to 16
	III	1 to 16
Breaking Strength	II	1 to 16
Water Conductivity	II	1 to 16
based on scion diameter at 5 cm.	III	1 to 16
based on union diameter	IV	1 to 3
Microscopic Evaluation	III	1 to 16
Macroscopic Evaluation	II	1 to 16
	III	1 to 16
Type of Break	II	1 to 16

RESULTS AND DISCUSSION

Hardiness

In the spring of 1951 it was observed that approximately 50% of the Ornamental seedlings were killed entirely or to the ground level. No injury was apparent in the other seedling lines.

The following spring (1952), 25% of the remaining Ornamental seedlings were killed to the ground level. There was still no visible injury to plants in the other seedling lines.

The Ornamental line, as mentioned earlier, came from no specific ornamental variety. It is possible that most of the seed was harvested from varieties or seedlings at Morden, Manitoba which are not fully hardy in Alberta. It is obvious that where rootstock hardiness is important only seed from varieties known to be hardy should be used, unless the variability in behaviour of seedlings of a variety is known to be within satisfactory hardiness limits.

Bud "Take"

Analysis of variance was applied to the "take" data reported in Appendix I. Table 1 summarizes the results of this analysis.

Table 1

Analysis of Variance

"Take" of Buds in 1953.

Variance due to	DF	Mean Square or Variance
Reps.	1	58.8
Scions	1	2261.3**
Rootstocks	7	19.6
Scions x Rootstocks	7	30.43**
Error	15	3.92

** Significant at 1% level.

M.S.D. Scions x Rootstocks - 4.0 buds.

No one rootstock appears to be best for both scion varieties. The scion/rootstock interaction indicates a differential response of varieties to rootstocks.

Within scion varieties when the scion/rootstock M.S.D. is applied to Columbia as a standard the "take" is significantly better on the following rootstocks:-

with Haralson - Dolgo and Beauty.

with Rescue - Beauty.

with Haralson - Dolgo is significantly better than Beauty.

No rootstock had a "take" significantly less than Columbia within either scion variety.

The M.S.D. for scions was not calculated. Rescue "take" was 89% and Haralson was significantly less with 55%.

Shoot Growth and Vigour

Extensive branching of the scion variety Rescue made it impossible to use shoot length as a quantitative measure of vigour. The correlation coefficients of scion diameter- shoot length (s) were calculated for the unbranched plants in Tables 9 and 13 Appendix II. The scion diameter at 1cm. (c) was used as well as the scion diameter at 5 cm. (i). The results were:

r_{sc}	+ .707	DF 30
r_{si}	+ .752	DF 30

Both values are highly significant.

The higher correlation with the scion diameter taken at 5 cm. is attributed to swellings from the union which in many cases affect the diameter at 1 cm. above the union. The 5 cm. measurement is considered a more reliable measure of shoot length, a conclusion established by the above comparison.

The regression equation was calculated for shoot length - scion diameter at 5 cm.

$S = 40.9 + 71.28i$

When i for certain branched Haralson shoots was substituted in the equation it was found that no fixed proportion of lateral growth could be applied to

the central shoot growth to produce the same value as the regression equation. However, in no case was the lateral growth less than that necessary to bring the measurement up to the calculated value.

The correlation of shoot and diameter of .752 was considered large enough to warrant the use of diameter as a measure of vigour especially when 20 values are used for each combination.

It was realized that stock diameter (d) doubtless would have an influence on scion size. The correlation of these factors was determined for the data in Tables 1 and 9 in Appendix II.

r_{di} .686 Table 1.

r_{di} .758 Table 9.

Both coefficients are highly significant. A similar correlation was noted by Gardner and Yerkes (12).

Analysis of covariance was applied to the data in Tables 1 to 16, Appendix II to remove the effect of stock diameter on scion size after analysis of variance had indicated that a scion/rootstock interaction was significant.

The results of these calculations are briefly reported in Tables 2 and 3.

Table 2

Analysis of Variance

Diameter of Scions at 5cm.

Variance due to	DF	Mean Square or Variance
Scions	1	.3717
Rootstocks	7	.0345
Scions x Rootstocks	7	.2024**
Error	304	.0397

**Significant at 1% level.

Table 3

Analysis of Covariance

Scion Diameter

Adjusted for Covariance of Scion

Diameter and Stock Diameter.

Variance due to	DF	Adjusted sum Squares	Mean Square or Variance
Scions x Rootstocks+E	310	7.5137	.0242
E	303	6.3931	.0211
Scions x Rootstocks	7	1.1206	.1601**
Scions x Rootstocks	6	1.0691	.1782**

**Significant at 1% level.

M.S.D. for Scions - Rootstock = .09cms.

Scion/rootstock means were adjusted by the covariance method and adjusted values are shown in Table 4.

Table 4

Mean Diameters of Scions in Centimetres

(adjusted for variation in stock diameters)

Scion Variety	Rootstock							
	Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Ornamental	Beauty
Haralson	.88	1.00	.90	.95	.97	.99	.99	.94
Rescue	.96	1.09	1.06	1.05	1.06	1.07	1.13	1.07

It is worthy of note that Haralson at no time exceeds Rescue in this measurement of vigour. The differences between the varieties are obvious but they are not discussed in this report.

Within the scion varieties the stocks do not vary to a great extent. Haralson on Bedford made significantly better growth than Haralson on Columbia and Rescue on Alberta made significantly less growth than Rescue on Columbia. In no other cases did the rootstocks differ from Columbia in their influence on the individual scion varieties.

Breaking Strength Tests

Correlation coefficients for Modulus of Rupture (b) and Scion Diameter at 5cm. (i) were calculated from data in Table 1 to 16, Appendix II and they are reported in Table 5.

Table 5

Correlation Coefficients for Modulus of Rupture and Diameter of Scion at 5cm.

Scion Variety	Rootstock: Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Ornamental	Beauty
Haralson	+.469*	+.453*	+.534*	+.105	+.487*	+.445*	+.488*	+.495*
Rescue	+.518*	+.302	+.493*	+.582*	-.169	+.392	+.340	+.300
				DF 18				
Haralson and Rescue	+.486**	+.391*	+.543**	+.372*	+.100	+.390*	+.435**	+.461**
				DF 38				

Haralson on all rootstocks	.339**	DF 158
Rescue on all rootstocks	.392**	
All combinations	.382**	DF 318

* Significant at 5% level.
** Significant at 1% level.

The observed discrepancies in coefficients are quite possibly due to sampling error. The correlation values while low indicate a definite relationship between modulus of rupture and scion diameter.

Partial correlation coefficients were calculated for the data that appear in Tables 1,5,8, and 9, Appendix II to determine whether the stock diameter influence on the scion diameter affected the correlation. Table 6 contains the comparisons.

Table 6

Correlation and Partial Correlation Coefficients for Scion Diameter and Modulus of Rupture.

Combination	With Stock Diameter Influence	Stock Diameter Influence Removed
Haralson on Alberta	+.469*	+.532*
Rescue on Alberta	+.518*	+.565**
Rescue on Beauty	+.300	+.401
Rescue on Elsa	-.169	-.083

*Significant at 5% level

**Significant at 1% level

The increase in covariation of the two factors for each of these combinations indicates that the positive relationship is even greater than that illustrated in Table 5.

The breaking strength data were deemed worthy of analysis. The results of this analysis are summarized in Table 7. The data used for the analysis were taken from Tables 1 to 16 Appendix II.

Table 7.

Analysis of Variance

Breaking Strength of Unions (Modulus of Rupture)

Variance due to	DF	Mean Square or Variance
Scions	1	98106
Rootstocks	7	24253
Scions x Rootstocks	7	42680
Error	304	14421

Significant at 1% level.

M.S.D. Scions/Rootstocks 76 pounds per squ. cm.

Arithmetic means for the combinations are as follows:

Scion	Alberta	Bedford	Columbia	Dolgo
Haralson	368	365	297	371
Rescue	312	428	351	392
	Elsa	Osman	Ornamental	Beauty
Haralson	367	350	266	342
Rescue	348	343	420	413

Within each scion variety Rescue on Bedford is the only combination which differs significantly from Columbia. Bedford has a stronger union with Rescue than has Columbia.

The high interaction is similar to that observed with scion diameter and again it indicates that no one rootstock is superior or inferior to Columbia when both scion varieties are considered.

Type of Break

The type of break data when compared to the other methods of evaluation did not reveal any trend. It is unlikely that this method of evaluation has any value for comparison of unions which do not differ appreciably from one another.

Water Conductivity Tests

Water conductivity as reported earlier was calculated by two methods. They are :

$$w = \frac{\text{actual water conductivity in ml. per 10 mins.}}{\text{area of scion 5cm. from the union.}}$$

$$v = \frac{\text{actual water conductivity in ml. per 10 mins.}}{\text{area of union based on mean of diameters measured 1cm. above and 1cm. below the union.}}$$

w is reported in Tables 1 to 16 Appendix II and Appendix III.
v is reported in Tables 1 and 2 Appendix IV and represents values for data in Tables 1 to 16 Appendix II only. The v values for data in Appendix III were only calculated for Tables 6 and 14 and are reported in Table 3, Appendix IV.

The correlation coefficients calculated for v and w, and other methods of evaluation are :

r_{wb}	$+.196^{**}$	r_{wi}	$+.074$
r_{vb}	$+.293^{**}$	r_{vi}	$+.236^{**}$

**Significant at 1% level. DF = 318

The coefficients for v and breaking strength(b) and v and scion diameter(i) indicate a correlation which although small is highly significant. It would not be safe to forecast values for b or i from conductivity readings however.

The reason for the improvement in correlation by using v in preference to w is not clear. The diameter formula used in calculating v was the same as that used by Chang (8), but w is based on the minimum observed diameter and this should be the limiting factor in some cases. These cases are evidently not numerous.

Analysis of variance was performed on the w and v data and is reported in Tables 8 and 9 respectively.

Table 8

Analysis of Variance.

Water Conductivity based on cross-sectional Area of Scion 5cm. from the Union.

(Data from Tables 1 to 16, Appendix II)

Variance due to	DF	Mean Square or Variance
Scions	1	223.95**
Rootstocks	7	47.03**
Scions x Rootstocks	7	19.14
Error	304	17.22

**Significant at 1% level.

M.S.D. Rootstocks $\simeq$ 1.9 ml.

Table 9

Analysis of Variance

Water Conductivity based on Cross-sectional Area of Union determined from the Diameter of Scion and Stock 1 cm. above and 1 cm. below the union.

(Data from Table 1 and 2, Appendix IV)

Variance due to	DF	Mean Square or Variance
Scions	1	135.59**
Rootstocks	7	11.86**
Scions x Rootstocks	7	5.05
Error	304	5.12

**Significant at 1% level.

M.S.D. Rootstocks = 1.0 ml.

When the minimum significant differences were applied to means for Columbia for each method of measuring conductivity the rootstocks which differed significantly from Columbia were the same. No rootstocks were superior to Columbia and the following were inferior: Alberta, Dolgo, Ornamental and Beauty.

Microscopic Evaluation

Correlation coefficients for the microscopic evaluation scores(e) and other methods of evaluation are listed below.

All data are from Appendix III except the ve data which are taken from Appendices III and IV.

	r_{we}	r_{ve}	r_{ie}
Haralson on Beauty	-.043	---	-.018
Haralson on Osman	+.250	+.380	+.013
Rescue on Osman	+.319	+.342	+.477*
Haralson on Alberta	----	----	-.070

*Significant at 5% level.

A trend in correlation may be indicated but not established for ve. Although the correlation for ie is significant for Rescue on Osman, the very low coefficients for the other three combinations indicate that no consistent correlation exists between i and e. Microscopic evaluation does not appear to be a good measure of compatibility if the other methods investigated can be assumed to be reliable standards. The relationship between breaking strength and microscopic evaluation could not be established as unions could not be both broken and sectioned.

Analysis of variance was performed on the data in Tables 1 to 16, Appendix III and is reported in Table 10.

Within scion varieties the following relationship to Columbia as a standard is evident:-

Within Haralson
Inferior - none
Superior - Alberta, Bedford, Osman and Ornamental.

Within Rescue

Dolgo inferior

Ornamental and Beauty superior

Table 10

Analysis of Variance

Microscopic Evaluation of Unions

Variance due to	DF	Mean Square or Variance
Scions	1	8.20
Rootstocks	7	9.86
Scions x Rootstocks	7	5.34**
Error	304	1.47

**Significant at 1% level.

M.S.D. = .8 score units

Macroscopic Evaluation

Correlation coefficients for macroscopic evaluation (m) and other methods of evaluation are reported in Table 11.

Macroscopic evaluation does not appear to be correlated with either breaking strength or water conductivity(w). The improvement in the correlation when water conductivity(v) is used is evident. Water conductivity(v) is more highly correlated with other methods of evaluation and therefore should be used in

preference to w.

Table 11

Correlation Coefficients
for Macroscopic Evaluation of Unions
and Other Methods of Evaluating Unions.

Combination	Methods of Evaluation				
	bm	wm	vm	mi	me
Rescue on Alberta	-.174	+.095	+.229	+.409	
Haralson on Alberta	+.279	+.302	+.530*	+.749**	
Rescue on Osman					+.751**
Haralson on Osman					+.297
Haralson on Beauty					+.362
Rescue on Dolgo				+.410	
All combinations				+.492**	

*Significant at 5% level.

**Significant at 1% level.

The correlation between macroscopic and microscopic evaluation is not established but a trend is evident. The highly significant correlation for m and i should be viewed with suspicion. It is possible that the size of the scion influenced the evaluator. Indeed it is very difficult to be free from bias when evaluating unions of varying size on a visual basis.

Analysis of variance was applied to the macroscopic evaluation data in Tables 1 to 16, Appendix II and the results are summarized in Table 12.

Table 12

Analysis of Variance

Macroscopic Evaluation of Unions

Variance due to	DF	Mean Square or Variance
Scions	1	12.0
Rootstocks	7	1.09
Scions x Rootstocks	7	2.03 *
Error	304	.83

*Significant at 5% level.

M.S.D. Scions x Rootstocks = .6 score units

When means are compared within each scion group with Columbia as a standard no rootstock was superior to Columbia and only Ornamental when in combination with Haralson was inferior.

Defoliation

No abnormal defoliation was observed in the rootstock seedlings during 1952 or in the Haralson and Rescue plants during 1953.

Diameter of Stock

The stock diameter is not considered

important in evaluating the stocks for their compatibility. The variability of the stocks is important however, and the effect of the scion on the stock growth is also worthy of determination.

Analysis of variance was carried out on stock diameter data in Tables 1 to 16, Appendix II and is summarized in Table 13.

Table 13

Analysis of Variance

Stock Diameters

Variance due to	DF	Mean Square or Variance
Scions	1	.2755 *
Rootstocks	7	.1451 *
Scions x Rootstocks	7	.0659
Error	304	.0676

*Significant at 5% level

M.S.D. Rootstocks = .12 cms.

No rootstock differs significantly from Columbia in diameter. The diameter of rootstocks under Rescue is significantly greater than the diameter of those under Haralson. It is possible that the more vigorous Rescue tree enables the rootstock to develop more rapidly. The influence of the scion on stock development has long been known. A comparison of the

rootstocks when they are older would be valuable. Swarbrick and Roberts (33) showed that certain scion varieties had a pronounced retarding effect on stock development in the first year. The scion influence observed here may be very important, and efforts will be made in the future to ascertain the duration of the influence.

GENERAL CONCLUSIONS

Following are certain conclusions based on the results and discussion reported elsewhere:

1. Comparisons of methods of evaluating the compatibility of stock/scion combinations have been less conclusive than had been hoped. The lack of a standard method of evaluation is a serious handicap. Many factors are correlated but none to a high degree.

(a) Microscopic and macroscopic methods are both unsatisfactory. The former is laborious and does not appear to be accurate enough to warrant its use. The macroscopic method is subject to bias by the evaluator and this bias itself is likely to be variable.

(b) Scion diameter, breaking strength and water conductivity are all significantly correlated. All of these methods produce values which are independent of the evaluator's judgement. These methods appear to be fairly reliable for evaluating stock/scion compatibility.

(c) Scion diameter is a good measure of top growth but is influenced by the size of the stock and should be adjusted for this factor.

2. Table 14 illustrates the lack of agreement of methods of evaluating compatibility when the data for each method is analyzed:

Table 14

Rootstocks which Differ Significantly from Columbia

Method of Evaluation	Superior to Columbia		Inferior to Columbia	
	Scion Variety		Scion Variety	
	Haralson	Rescue	Haralson	Rescue
Scion Diameter	Bedford	Ornamental	none	none
Breaking Strength	none	Bedford	none	none
Water Conductivity	none	none	Alberta	Alberta
			Dolgo	Dolgo
			Osman	Osman
			---Ornamental--	
Macroscopic Evaluation	none	none	Ornamental	none
Microscopic Evaluation	Alberta	Beauty	none	Dolgo
	---Ornamental---			
	Bedford			
	Osman			
"Take" of Buds	Beauty	Beauty	none	none
	Dolgo			

No two methods yield identical results. An examination of the means for scion diameter and breaking strength reveals that Alberta, Dolgo and Osman have lower

values than Columbia. The breaking strength means for Haralson also indicate that Ornamental is somewhat lower than Columbia but not significantly so. The apparent discrepancy in the water conductivity results is therefore not as pronounced as it appears superficially and the three methods favoured because of their correlation may be said to yield similar results.

3. The difficulty experienced in establishing the superiority or inferiority of a particular rootstock line indicates that the lines used in this investigation do not differ greatly in their compatibility with the scion varieties used. It is also evident that no one rootstock is superior or inferior to the other rootstocks for both scion varieties.

4. The lack of hardiness evident in the Ornamental line strongly indicates the value of using crabapple varieties of known hardiness for a source of rootstock seed.

5. Stock measurements indicate little variability between the rootstock lines but a scion influence upon the stock is established.

6. "Take" of buds does not appear to be a measure of compatibility but rootstock/scion combinations do differ significantly in their "take". The "take" results should not be considered conclusive as the successful uniting of buds to any reasonably compatible stock may vary considerably from year to year and certain environmental conditions may be more favourable for some combinations than others.

SUMMARY

1. A series of investigations was conducted from 1950 to 1953 to compare eight seedling apple rootstock lines with respect to their influence upon the performance of two scion varieties budded upon them. The lines were grown from seed of the following crabapple varieties: Alberta, Bedford, Columbia, Dolgo, Elsa, Osman, Ornamental (a mixture of ornamental varieties) and Beauty. Each line was budded to the apple varieties Rescue and Haralson.

The compatibility of the combinations was studied by the following methods:

(a) "Take" of buds.

(b) Vigour of top growth.

(c) Breaking strength of the unions.

(d) Water conductivity through the unions.

(e) Microscopic evaluation of sections from the unions.

(f) Macroscopic evaluation of unions.

(g) Type of break at the union.

(h) Observation of premature defoliation.

2. Methods of evaluation were compared by determining their correlation where possible.

3. Rootstocks were compared by analyzing the data from each test for which analysis was applicable.

4. The rootstock variability was assessed by measuring the diameter of the rootstocks.

5. The only methods of evaluating compatibility which appear to be reliable are vigour of top growth, breaking strength of the unions and water conductivity through the unions.

6. Scion diameter appears to be a good measure of top growth: i.e. vigour of the scion.

7. The adjustment of scion diameters for variability in stock size is necessary if accurate comparisons are to be made.

8. No one rootstock appears to be superior or inferior for both scion varieties.

9. The rootstocks do not differ significantly in their variability.

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APPENDIX I

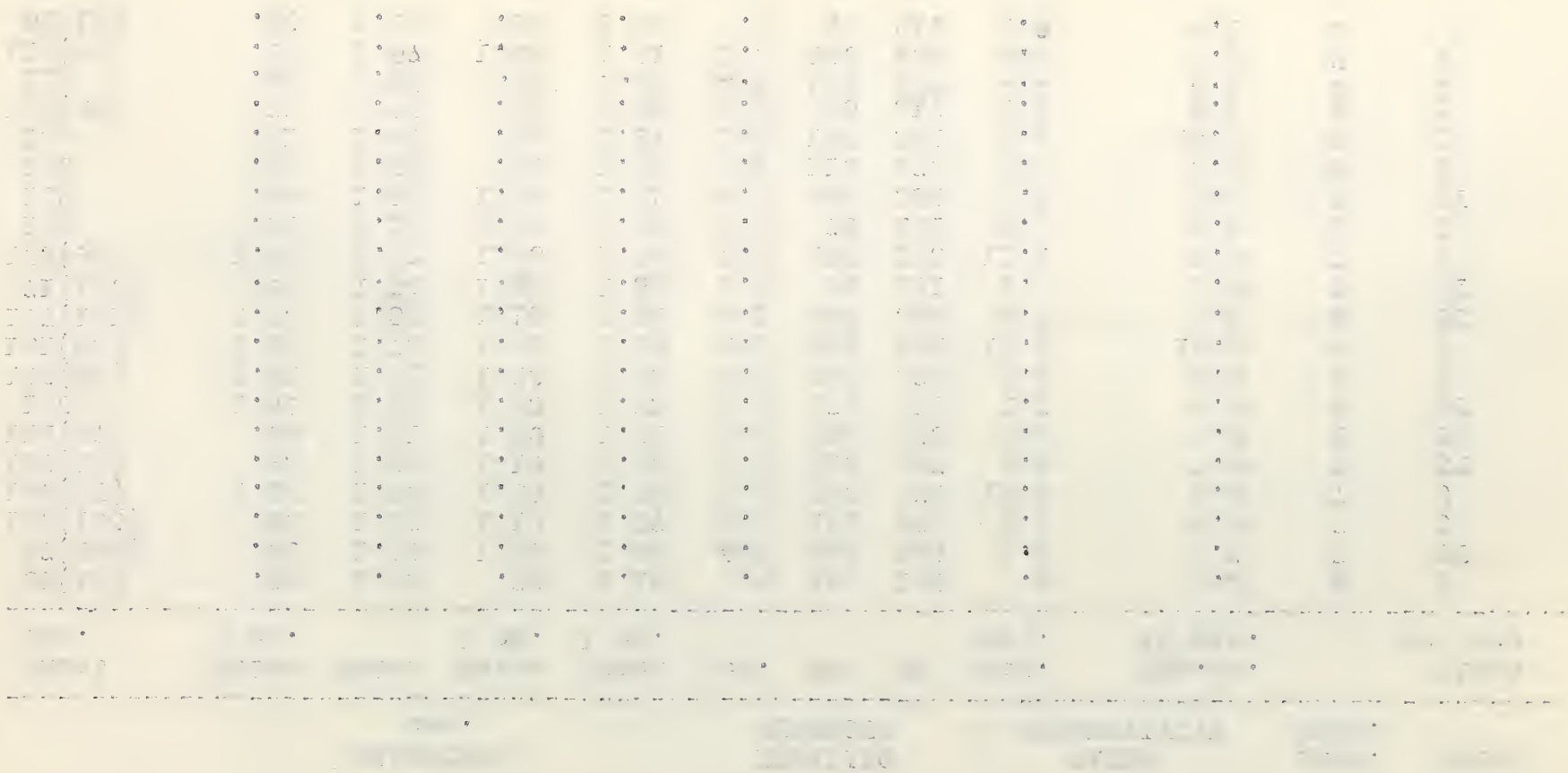
"Take" of 50 Buds.

Scion Variety	Rootstock							
	Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Ornamental	Beauty
Replicate 1.								
Haralson	37	30	29	36	37	35	28	33
Rescue	42	43	45	39	44	49	46	48
Replicate 2.								
Haralson	14	19	18	39	15	18	24	29
Rescue	46	46	39	43	47	43	44	46

APPENDIX II
Table 1

Rescue on Alberta Data.

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
58(18)	.70	1.43	.76	1.10	.9	45	156	.9	2.3	8	T
87(468)	.92	1.74	1.04	1.20	4.8	240	464	1.8	2.7	7	CT
125(196)	.95	1.67	1.10	1.77	2.5	125	273	3.5	4.9	7	C
149(25)	1.26	1.85	1.50	1.70	5.9	295	474	10.5	8.4	7	C
136(15)	.93	1.68	1.10	1.45	2.3	115	247	5.0	7.4	8	CT
114(67)	.99	1.91	1.09	1.62	3.6	180	263	2.3	3.0	8	CT
106	1.00	2.03	1.03	1.73	3.5	175	213	1.7	2.2	9	CT
146(20)	1.21	2.01	1.36	2.03	6.0	300	376	5.3	4.6	9	T
121(83)	1.30	1.73	1.44	1.59	5.0	250	492	13.5	10.2	9	C
107(161)	1.03	1.80	1.16	1.72	4.1	205	358	5.7	6.8	8	TC
71(145)	.90	1.54	1.00	1.36	1.8	90	251	1.0	1.6	8	CT
153(98)	1.26	2.27	1.55	1.90	5.8	290	253	11.1	8.9	7	C
134	.92	1.56	1.00	1.54	1.5	75	201	4.5	6.8	8	C
158	.99	1.80	1.08	1.61	4.4	220	384	5.1	6.6	7	CT
145	.87	1.62	.95	1.46	2.3	115	275	2.0	3.4	8	C
130	.81	1.45	.90	1.27	2.0	100	334	5.4	10.5	8	CT
110(20)	.77	1.45	.90	1.63	1.9	95	317	1.3	2.8	6	C
112	.96	1.64	1.08	1.32	2.2	110	254	2.5	3.4	8	C
114(80)	.90	1.57	1.00	1.41	3.3	165	434	2.5	3.9	7	T
62(15)	.56	1.28	.64	1.34	.9	45	219	1.0	4.1	6	T



APPENDIX II
Table 2

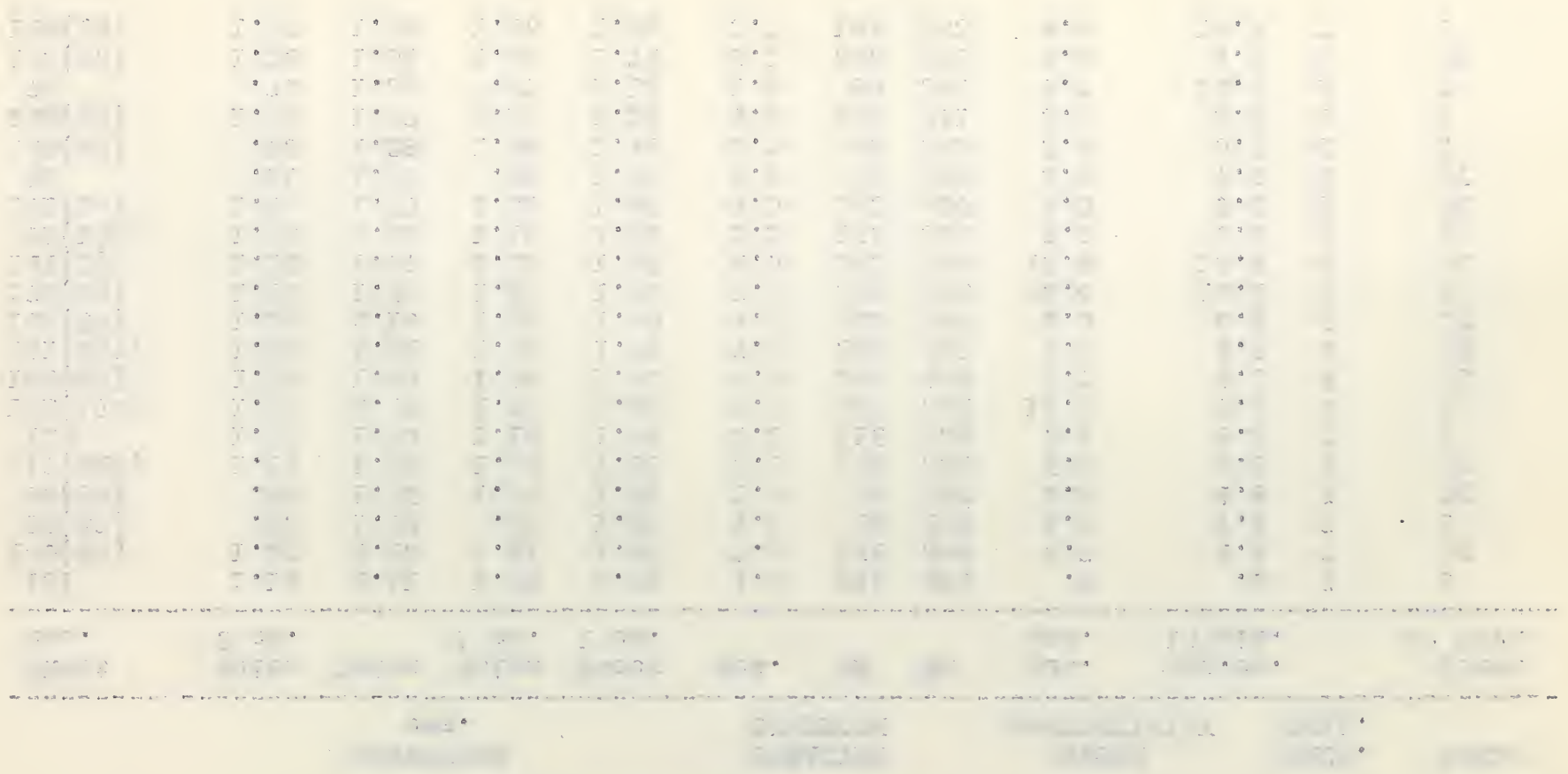
Rescue on Bedford Data.

	DIAMETERS				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act.	Squ.cm. 10 min.		Clean or Torn
133(90)	1.18	1.80	1.40	1.64	5.6	280	489	13.9	12.7	9	C
83	.83	1.31	.90	1.14	1.9	95	430	4.9	9.1	9	CT
112(5)	1.01	1.54	1.17	1.76	3.6	180	502	4.7	5.9	9	C
120	1.04	1.55	1.24	1.35	2.9	145	397	2.2	2.6	9	CT
78	.80	1.79	.87	1.66	1.7	85	151	.5	1.0	7	C
152(173)	1.50	2.10	1.63	1.80	7.8	390	429	3.0	1.7	8	CT
154(145)	1.39	1.98	1.51	1.74	6.6	330	433	7.7	5.1	9	TC
143(15)	1.24	1.70	1.37	1.38	6.8	340	705	10.2	8.4	8	CT
88(118)	.98	1.61	1.14	1.26	3.7	185	452	2.2	2.9	8	C
144(30)	1.12	2.06	1.19	1.36	4.1	205	239	2.4	2.4	6	CT
132	1.10	1.66	1.37	1.44	7.3	365	813	5.5	5.8	7	C
93(167)	.89	1.63	1.03	1.50	2.7	135	318	4.1	6.6	8	TC
120(316)	1.04	2.17	1.15	1.90	3.4	170	169	3.3	3.9	8	T
75	.60	1.10	.83	.84	.8	40	306	1.4	4.9	7	C
134(65)	1.17	1.72	1.28	1.38	4.9	245	490	9.1	8.5	9	C
146(35)	1.06	1.58	1.33	1.54	4.0	200	516	3.2	3.6	7	C
162(104)	1.39	2.00	1.56	1.68	6.9	345	439	13.9	9.2	8	C
96(25)	.82	1.27	.92	1.07	2.4	120	597	6.2	11.7	8	C
91(30)	.77	1.29	.89	1.06	1.7	85	403	4.8	10.3	7	C
129	.86	1.52	.89	1.44	1.9	95	276	2.8	4.8	7	T

APPENDIX II
Table 3

Rescue on Columbia Data.

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
131	1.12	2.11	1.36	2.00	4.9	245	265	.9	.9	7	C
149(49)	1.26	2.23	1.41	1.90	7.5	375	344	5.7	4.6	7	TC
84(57)	.85	1.46	.90	1.30	1.7	85	278	4.3	7.6	7	C
95(39)	.85	1.55	1.00	1.31	1.9	95	257	2.6	4.6	7	CT
117(220)	1.17	1.80	1.32	1.81	3.8	190	332	5.2	4.8	9	CT
124	1.02	1.70	1.18	1.64	2.3	115	238	5.1	6.2	7	C
162(170)	1.53	2.18	1.66	2.22	7.0	350	344	15.6	8.5	9	C
162(45)	1.32	1.90	1.46	1.80	6.0	300	446	6.7	4.5	9	TC
141(267)	1.32	1.92	1.52	1.76	7.6	380	547	9.0	6.6	9	CT
158(20)	1.25	2.10	1.36	1.89	4.5	225	247	8.3	6.8	6	CT
172(30)	1.28	1.90	1.50	1.82	7.3	365	542	23.4	18.2	9	C
141(5)	1.13	1.97	1.28	1.80	4.9	245	326	13.4	13.4	8	TC
92(156)	1.02	1.68	1.16	1.62	3.3	165	354	7.6	9.3	8	C
141(10)	1.11	1.72	1.31	1.50	4.5	225	450	9.5	9.8	8	TC
88	.81	1.69	.92	1.23	1.8	90	190	3.9	7.6	8	CT
120(45)	.95	1.58	1.06	1.44	2.5	125	323	3.9	5.5	8	C
102(10)	1.00	1.77	1.16	1.38	4.8	240	441	3.0	3.8	8	C
74	.75	1.32	.87	1.13	1.6	80	354	4.7	10.6	8	C
143(35)	1.35	1.91	1.50	1.70	6.1	305	446	6.9	4.8	8	TC
140(15)	1.09	1.86	1.25	1.60	3.7	185	293	9.3	10.0	7	C



APPENDIX II
Table 4

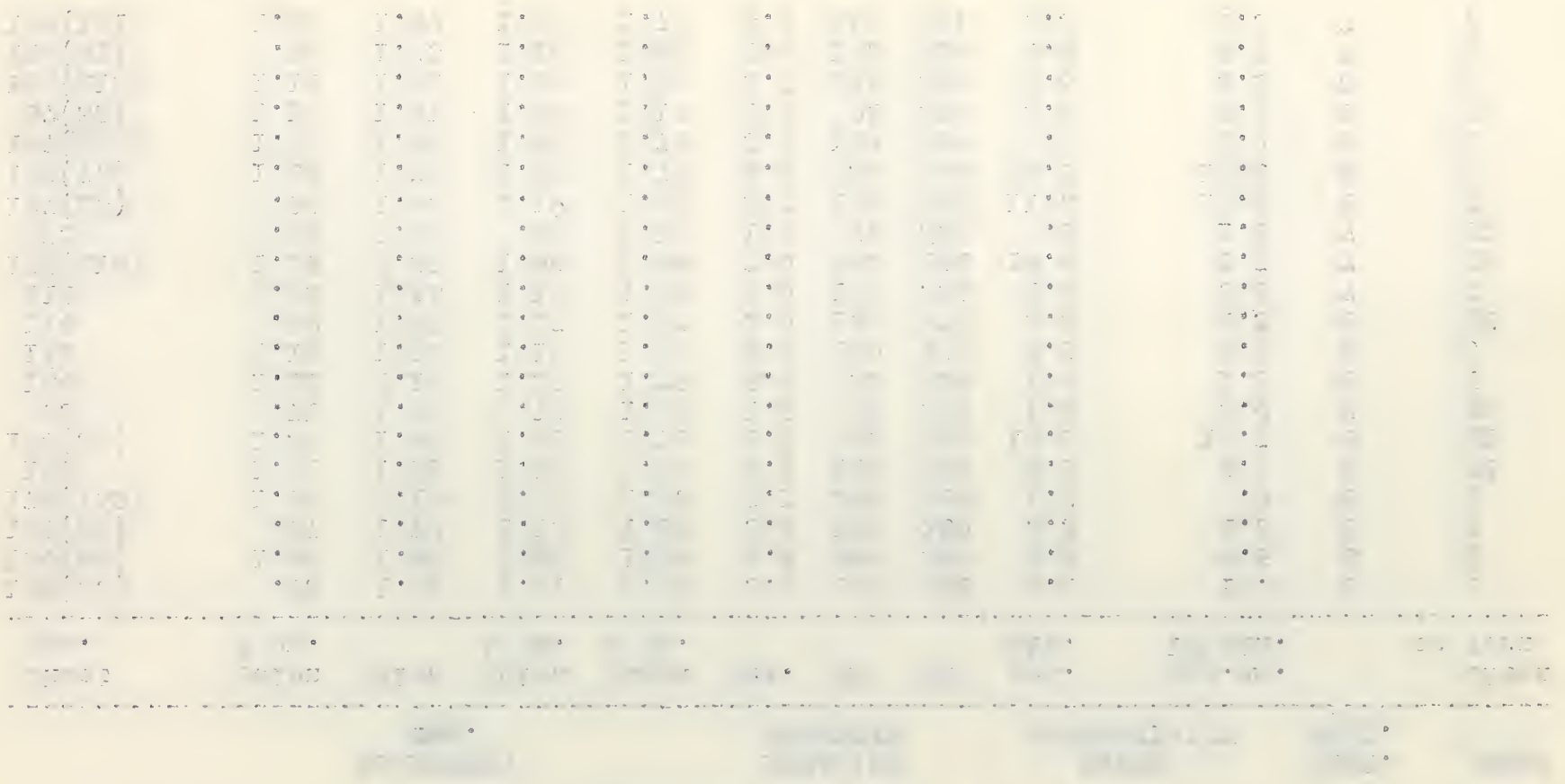
Rescue on Dolgo Data

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
148(99)	1.25	1.83	1.43	1.81	6.0	300	499	13.9	11.3	8	T
140	.84	1.61	.99	1.36	2.1	105	256	20.4	36.8	6	CT
113(181)	1.15	1.78	1.39	1.76	5.1	255	461	3.7	3.6	8	C
54	1.25	1.86	1.36	1.67	6.0	300	475	10.4	8.6	7	CT
143	1.10	1.70	1.22	1.59	4.5	225	466	6.0	6.3	8	T
171(32)	1.34	1.97	1.51	1.76	8.3	415	553	5.3	3.8	9	TC
114(284)	1.27	1.89	1.43	1.80	7.0	350	528	8.8	7.0	9	T
127	1.25	1.96	1.31	1.78	4.0	200	271	4.6	3.7	7	C
119	1.00	1.79	1.10	1.54	4.0	200	355	1.2	1.5	7	T
146(19)	1.34	1.73	1.40	1.74	6.0	300	590	4.9	3.5	8	C
110(111)	.93	2.14	1.11	1.92	3.3	165	171	5.3	7.8	8	T
99(167)	1.08	1.93	1.19	1.77	3.9	195	276	2.3	2.5	6	C
108(144)	1.12	1.54	1.21	1.61	3.3	165	460	3.1	3.1	8	CT
120(27)	1.23	1.87	1.35	1.76	5.8	290	452	4.9	4.1	9	T
83(20)	.89	1.61	1.03	1.50	3.2	160	391	2.8	4.5	6	C
93(56)	.77	1.42	1.05	1.28	2.4	120	427	2.4	5.1	7	T
137(142)	1.36	1.94	1.48	1.73	6.0	300	419	5.3	3.6	7	C
103(64)	1.00	1.60	1.12	1.36	3.5	175	435	6.5	8.3	7	T
93	.85	2.19	.98	1.97	1.9	95	92	1.5	2.6	6	C
118(97)	1.18	1.89	1.35	1.45	3.4	170	256	1.2	1.1	7	C

APPENDIX II
Table 5

Rescue on Elsa Data

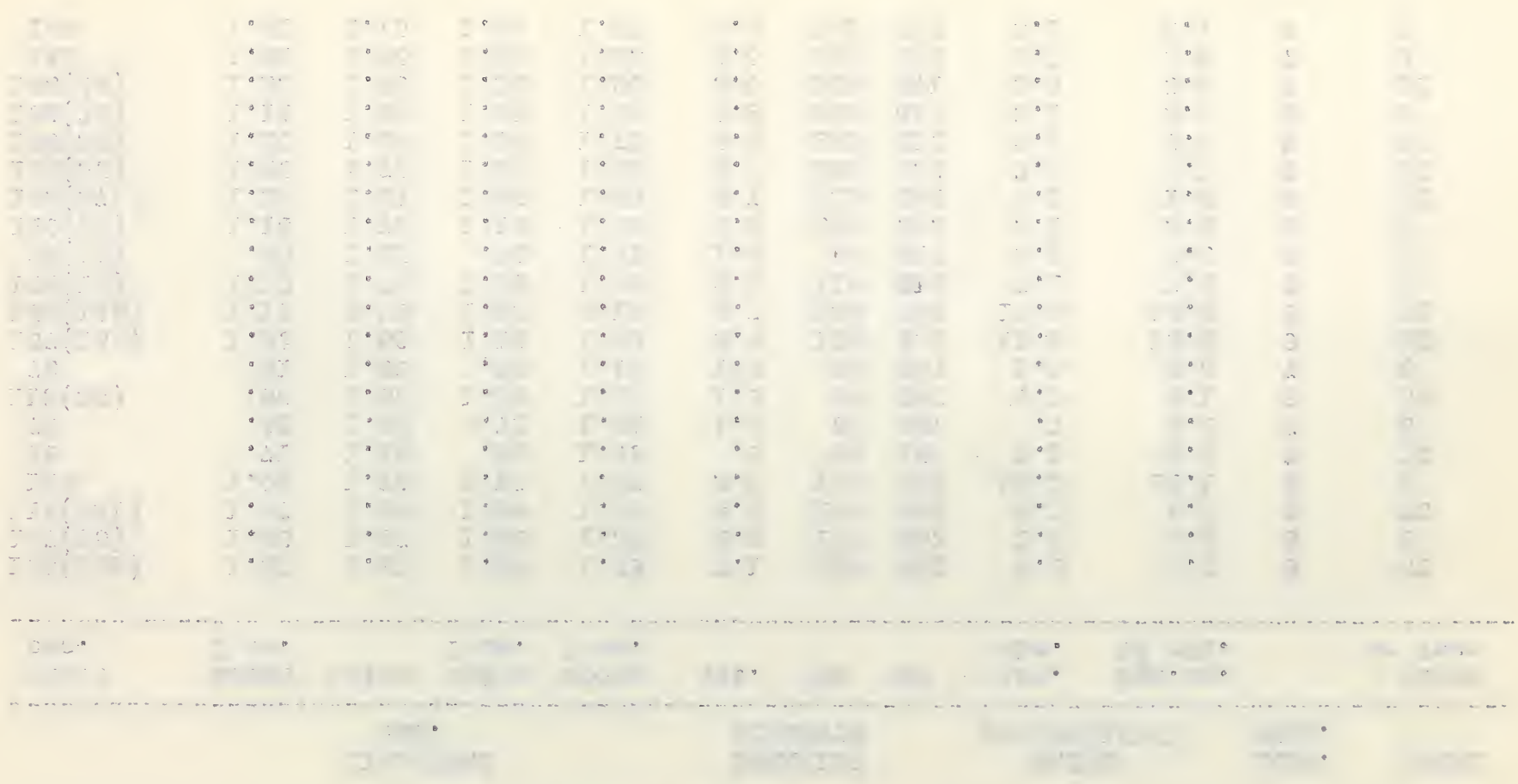
	DIAMETERS Cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
108(55)	.93	1.54	1.11	1.35	3.6	180	502	9.1	13.4	8	T
130(60)	1.22	1.90	1.36	1.92	4.8	240	356	6.5	5.6	8	C
127(60)	.97	1.72	1.13	1.60	3.2	160	320	3.3	4.5	8	T
175(152)	1.55	2.16	1.69	1.95	7.1	355	359	1.7	.9	9	C
106	1.01	1.83	1.12	1.46	2.4	120	199	4.9	6.1	8	TC
164(35)	1.33	1.94	1.58	1.75	5.1	255	356	14.8	10.7	9	CT
93	.71	1.27	.76	1.55	1.6	80	398	1.2	3.0	7	TC
154	1.22	2.18	1.37	1.78	6.6	330	324	1.5	1.3	8	T
142	1.10	1.70	1.19	1.50	4.6	230	476	6.6	6.9	9	C
114	.99	1.78	1.17	1.57	3.0	150	270	3.3	4.3	9	CT
114	.93	1.45	1.12	1.55	2.0	100	334	2.2	3.2	7	C
165(218)	1.69	2.38	1.96	1.99	7.0	350	264	19.6	8.7	7	TC
73	.58	1.29	.68	1.12	1.5	75	356	.5	1.9	7	TC
127(25)	.96	1.55	1.10	1.60	3.6	180	492	11.5	15.9	8	T
146(75)	1.20	1.74	1.32	1.70	4.6	230	445	14.9	13.2	8	C
147(224)	1.22	1.79	1.40	1.75	3.6	180	320	9.4	8.0	8	T
97(38)	1.14	1.47	1.09	1.19	1.9	95	305	3.6	3.5	8	TC
102(213)	1.14	1.72	1.25	1.54	3.7	185	370	3.3	3.2	8	C
118(91)	.90	1.75	1.16	1.64	2.5	125	238	2.5	3.9	7	C
146(141)	1.22	1.99	1.30	1.72	4.2	210	271	5.3	4.5	7	T



APPENDIX II
Table 6

Rescue on Osman Data.

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
158(148)	1.35	1.87	1.50	1.79	7.1	358	553	9.5	6.6	9	CT
107(35)	1.06	1.57	1.24	1.30	2.0	100	263	1.6	1.8	8	C
114(231)	1.07	1.98	1.28	1.98	4.0	200	262	5.3	5.9	7	TC
120	1.04	1.76	1.17	1.57	3.8	190	355	10.3	12.1	8	C
85	.71	1.45	.85	1.05	.9	45	150	2.1	5.3	7	TC
79	.63	1.25	.73	1.01	1.0	50	261	.7	2.2	7	C
113(30)	.86	1.50	1.00	1.23	1.9	95	287	4.7	8.1	8	CT
72	.81	1.50	.87	1.14	1.9	95	287	1.2	2.3	7	C
107(164)	1.05	1.66	1.16	1.40	3.9	195	434	11.8	13.6	9	CT
150(145)	1.13	2.19	1.23	2.10	4.7	235	228	10.5	10.5	9	TC
142(10)	1.10	1.75	1.18	1.48	2.3	115	219	7.2	7.6	8	C
70(77)	.80	1.25	.96	1.05	1.6	80	417	3.6	7.2	7	C
120(99)	1.14	1.73	1.14	1.59	4.0	200	393	3.1	3.0	8	T
143(371)	1.38	2.27	1.46	1.98	6.7	335	292	2.0	1.3	8	CT
155(35)	1.25	1.76	1.38	1.66	3.6	180	336	7.0	5.7	7	CT
152(30)	1.20	1.80	1.38	1.75	5.9	295	515	8.6	7.6	8	C
156(74)	1.14	1.80	1.28	1.64	4.8	240	419	3.1	3.0	9	C
162(49)	1.23	1.90	1.38	1.80	5.0	250	371	3.9	3.3	7	CT
142	1.01	1.55	1.16	1.25	3.6	180	492	2.7	3.8	7	C
159	1.32	2.15	1.46	1.87	6.5	325	333	3.3	2.4	8	C



APPENDIX II
Table 7

Rescue on Ornamental Data.

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
150(20)	1.19	1.67	1.22	1.62	4.7	235	514	5.6	5.0	8	C
148(70)	1.37	2.00	1.61	1.70	6.8	340	433	5.5	3.7	8	C
131(30)	1.14	1.75	1.28	1.50	4.8	240	456	4.5	4.4	7	C
144(55)	1.08	1.69	1.28	1.58	4.1	205	433	8.0	8.7	8	C
156(100)	1.23	1.90	1.37	1.70	4.8	240	356	7.9	6.6	8	C
113(390)	1.41	1.90	1.55	1.79	7.0	350	520	12.7	8.1	8	C
161(153)	1.23	1.73	1.45	1.80	6.4	320	630	7.0	5.9	9	T
150(110)	1.39	1.95	1.50	1.81	6.8	340	467	4.7	3.1	9	TC
103(105)	1.01	1.54	1.14	1.14	3.5	175	488	4.0	5.0	7	C
150(25)	1.22	1.80	1.31	1.52	5.2	260	454	7.2	6.2	8	C
147(128)	1.43	2.01	1.62	1.81	5.7	285	357	14.1	8.8	8	C
107(127)	1.02	1.87	1.16	1.61	3.8	190	296	3.6	4.4	9	T
125(60)	1.11	1.83	1.28	1.70	3.8	190	316	3.9	4.0	8	C
106	.84	1.61	.96	1.18	2.3	115	281	2.3	4.2	7	TC
137	1.10	1.70	1.28	1.69	4.7	235	487	2.4	2.5	9	TC
113(45)	1.00	1.57	1.14	1.36	2.9	145	382	3.2	4.1	9	C
110(45)	1.00	1.52	1.14	1.27	3.4	170	493	5.7	7.3	8	C
128(62)	1.05	1.61	1.22	1.52	2.6	130	317	5.3	6.1	9	TC
108(20)	.94	1.45	1.02	1.09	1.7	85	284	1.4	2.0	8	C
65(20)	.73	1.20	.87	1.09	1.5	75	442	1.0	2.4	7	TC

APPENDIX II
Table 8

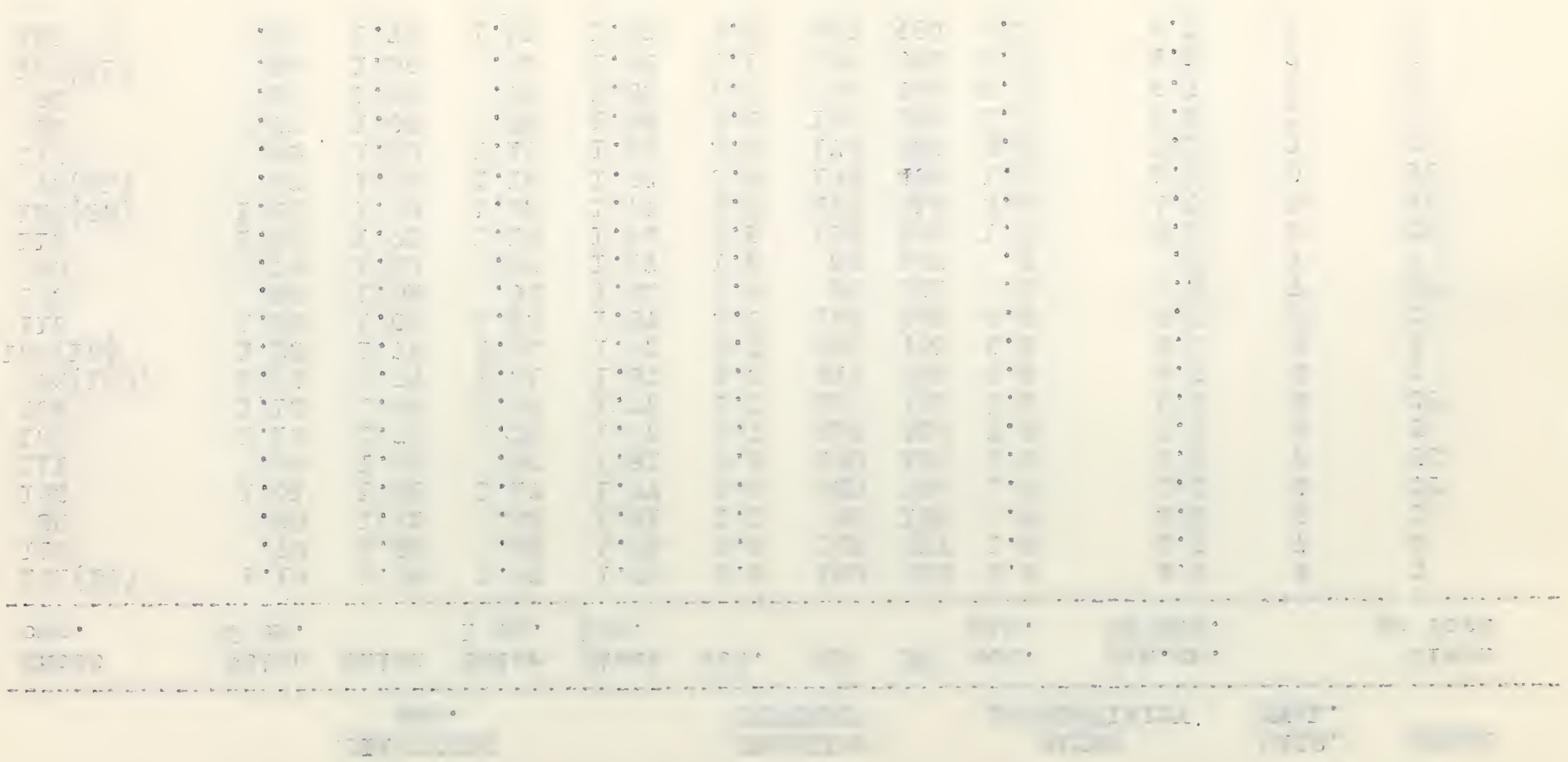
Rescue on Beauty Data.

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act.	Squ.cm. 10 min.		Clean or Torn
130	1.00	1.78	1.12	1.70	4.0	200	361	2.0	2.5	8	T
125(5)	1.16	1.72	1.28	1.52	4.1	205	410	8.4	7.9	9	C
134(59)	1.16	1.79	1.38	2.00	5.5	275	488	13.9	13.2	9	C
90(73)	.92	1.32	1.01	1.17	2.3	115	509	3.9	5.9	9	TC
144(262)	1.31	1.72	1.37	1.80	6.4	320	641	11.3	8.4	8	TC
140(40)	1.05	1.55	1.28	1.50	4.3	215	588	3.8	4.4	9	C
87	.92	1.38	.95	1.23	1.9	95	368	1.2	1.8	8	C
108(142)	1.11	1.72	1.25	1.50	2.9	145	290	2.8	2.9	9	C
106	.96	1.78	1.07	1.41	3.5	175	316	4.1	5.7	8	TC
154(335)	1.67	2.35	1.85	1.85	10.8	540	424	9.3	4.2	9	C
156	1.14	2.13	1.37	1.87	5.0	250	279	7.1	7.0	8	TC
130(25)	1.10	1.96	1.23	1.55	4.1	205	277	5.3	5.6	8	TC
135	.98	1.92	1.17	1.93	3.7	185	266	2.2	2.9	8	TC
144(10)	1.16	1.74	1.27	1.75	4.6	230	445	8.9	8.4	9	TC
152(80)	1.23	1.97	1.43	1.93	6.4	320	426	7.0	5.9	9	C
109	.96	1.47	1.11	1.48	2.5	125	401	3.2	4.4	9	TC
100(25)	1.08	1.58	1.16	1.31	4.8	240	620	1.4	1.5	8	T
90	.72	1.39	.80	1.13	1.6	80	303	1.5	3.3	8	T
140(374)	1.42	2.19	1.66	1.85	9.6	480	466	14.6	9.2	9	T
85(116)	.86	1.61	1.02	1.35	3.2	160	391	1.6	2.8	8	TC

APPENDIX II
Table 9

Haralson on Alberta Data.

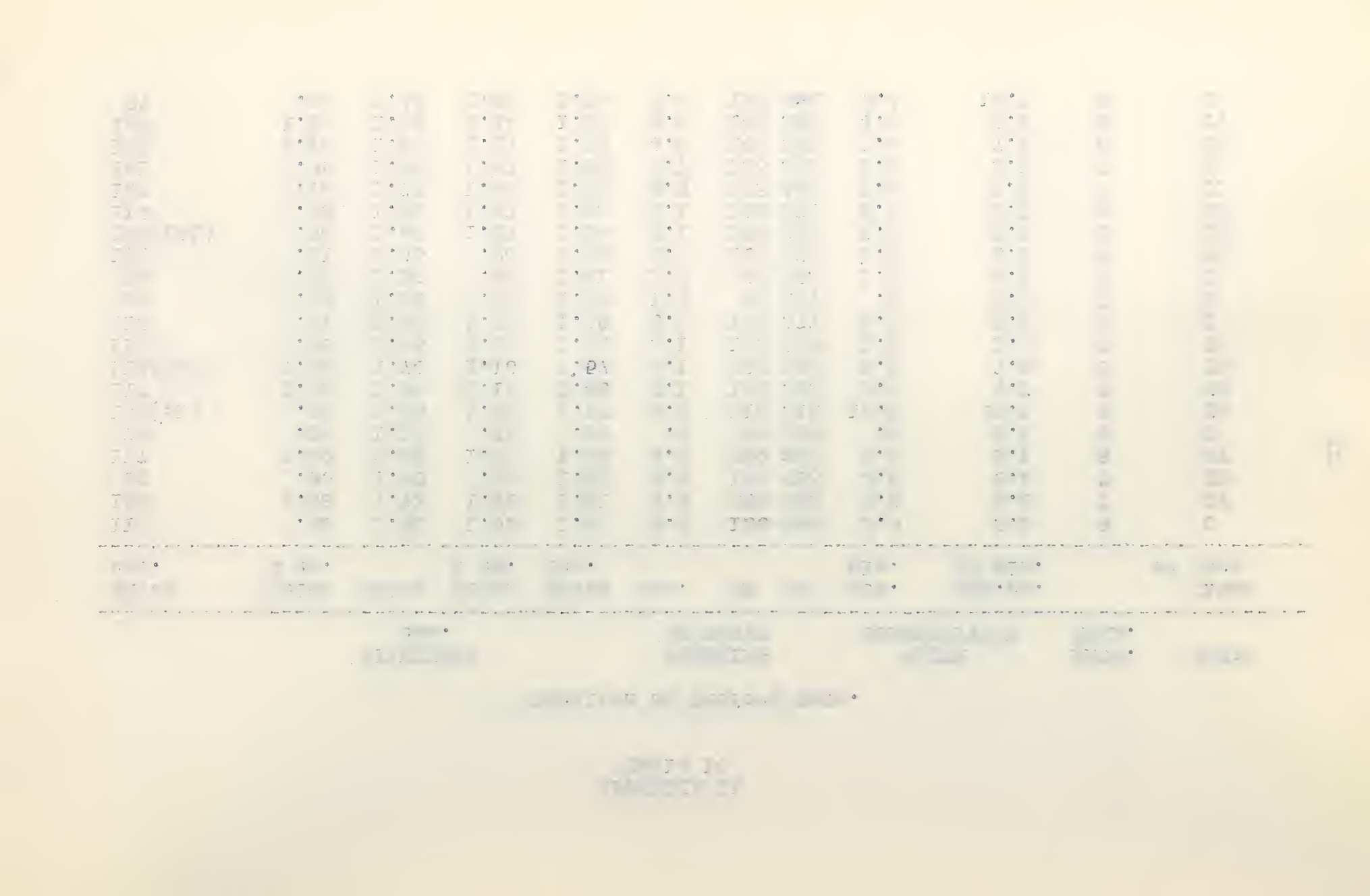
	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
102(54)	1.19	1.90	1.37	1.70	3.2	160	238	4.5	4.0	9	C
110	.79	1.50	.94	1.55	2.5	125	377	1.3	2.7	7	C
82	.60	1.42	.68	1.41	1.1	55	196	.9	3.2	6	T
126	1.01	1.85	1.17	1.77	4.4	220	354	1.9	2.4	6	CT
111	.88	1.88	.96	1.81	2.4	120	184	1.2	2.0	7	TC
130	1.13	1.76	1.38	1.43	4.7	235	439	7.9	7.9	9	T
134	1.13	1.84	1.25	1.75	5.6	280	458	1.2	1.2	9	CT
92(159)	1.34	1.77	1.31	1.67	4.3	215	395	6.6	4.7	8	C
134(15)	1.23	1.78	1.30	1.83	5.0	250	451	6.4	5.4	8	T
116	1.09	1.64	1.13	1.57	3.9	195	450	8.4	9.0	8	C
103	.88	1.52	.95	1.52	1.8	90	261	.8	1.3	7	CT
89	.79	1.40	.87	1.17	1.6	80	297	.2	.5	7	T
116	1.03	1.73	1.19	1.84	3.6	180	354	1.9	2.3	8	CT
122(25)	1.23	1.79	1.23	1.77	5.8	290	515	5.4	4.5	9	CT
95(61)	.97	1.59	1.10	1.67	3.9	195	494	1.4	1.9	6	CT
116	.99	1.60	1.15	1.85	3.5	175	434	5.6	7.3	7	T
94	.77	1.68	.95	1.58	2.4	120	258	1.3	2.8	7	T
80	.69	1.25	.78	1.25	1.8	90	469	2.5	6.7	6	C
102(81)	.86	1.56	.90	1.52	2.1	105	282	2.4	4.1	7	T
121	.98	1.72	1.11	1.67	4.5	225	450	4.3	5.7	8	T



APPENDIX II
Table 10

Haralson on Bedford Data.

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
112	.88	1.55	1.05	1.37	2.5	125	342	2.0	3.3	8	C
124	1.08	1.73	1.15	1.61	4.4	220	433	2.6	2.8	7	CT
92	.95	1.50	.94	1.22	2.8	140	423	3.8	5.4	7	TC
117	1.09	2.00	1.20	1.69	4.4	220	280	2.0	2.1	8	CT
78	.65	1.18	.75	.98	.8	40	248	.8	2.4	6	C
100(51)	.90	1.55	1.00	1.17	2.2	110	312	18.8	29.6	8	TC
117	1.03	1.59	1.14	1.42	3.1	155	393	3.9	4.7	7	TC
118(10)	1.04	1.74	1.16	1.57	4.1	205	396	6.1	7.2	9	TC
110	.99	1.55	1.13	1.32	3.1	155	424	1.5	1.9	7	TC
116	.91	1.52	1.00	1.48	2.6	130	377	4.0	6.2	8	C
90	.72	1.35	.77	1.50	1.0	50	207	.9	2.2	7	C
80	.70	1.36	.85	1.21	1.3	65	263	1.9	4.9	6	C
102	.91	1.65	.96	1.68	2.4	120	272	1.6	2.5	7	TC
100(141)	.96	1.68	1.27	1.56	6.1	305	655	6.5	9.0	8	TC
114	.95	1.58	1.07	1.43	2.1	105	271	6.2	8.7	8	CT
127	1.15	1.70	1.24	1.53	4.5	225	466	6.6	6.4	8	TC
121	.95	1.62	1.07	1.25	2.7	135	323	2.2	3.1	7	C
133	1.14	1.84	1.34	1.73	4.8	240	392	7.4	7.4	8	CT
139	1.14	1.83	1.34	1.86	4.8	240	399	4.4	4.3	9	CT
87	.83	1.44	1.02	1.28	2.5	125	426	5.4	10.0	6	C



APPENDIX II
Table 11

Haralson on Columbia Data.

	DIAMETERS Cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
132	1.04	1.70	1.18	1.65	3.4	170	352	8.1	9.5	8	TC
128	.99	1.64	1.16	1.45	3.5	175	404	7.5	9.7	9	C
122	1.12	1.84	1.22	1.47	4.9	245	401	2.3	2.3	9	T
68	.52	1.58	.60	1.45	.8	40	134	.2	.9	6	T
94	.77	1.40	.94	1.18	1.7	85	316	3.6	7.7	7	C
117	1.00	1.77	1.10	1.62	2.9	145	266	2.5	3.2	8	CT
124	1.06	1.66	1.14	1.45	3.3	165	367	7.3	8.3	9	T
83	.74	1.49	.87	1.11	2.0	100	308	6.3	14.6	6	C
118	.98	1.59	1.16	1.51	4.2	210	532	8.8	11.7	9	C
103	.78	1.73	.95	1.41	2.0	100	197	2.1	4.4	6	T
107	.80	1.30	.95	1.18	2.0	100	464	5.3	10.5	9	CT
111	.94	1.73	.98	1.70	2.0	100	197	1.1	1.6	7	TC
97	.81	1.47	.91	1.45	2.6	130	417	1.5	2.9	8	T
105	.93	1.75	1.10	1.46	2.3	115	219	1.0	1.5	7	TC
69(40)	.76	1.70	.78	1.74	1.6	80	145	2.5	5.5	6	C
87	.72	2.06	.91	1.65	1.6	80	93	.9	2.3	7	T
105	1.14	1.91	1.28	2.05	4.8	240	351	1.2	1.2	9	C
63	.59	1.32	.66	1.27	.8	40	177	1.9	6.9	8	TC
80	.71	1.34	.87	1.17	1.6	80	339	9.8	24.7	8	T
96	.79	1.56	.92	1.42	2.0	100	268	.9	1.8	7	C

APPENDIX II
Table 12

Haralson on Dolgo Data

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
123	1.20	1.76	1.28	1.73	4.9	245	458	2.5	2.2	7	C
116	1.06	1.75	1.30	1.64	4.4	220	418	4.2	4.8	8	C
88	.87	1.37	1.01	1.55	.7	35	139	.2	.3	6	C
117	1.20	1.78	1.67	1.68	5.5	275	497	4.6	4.1	9	CT
117	1.05	1.81	1.24	1.65	3.8	190	306	.9	1.0	9	CT
108(134)	1.26	1.90	1.38	1.78	3.7	185	275	8.1	6.5	8	CT
128	1.06	1.66	1.21	1.58	4.0	200	445	.9	1.0	8	T
117	1.15	1.88	1.32	1.85	3.8	190	291	.4	.4	8	C
118	1.03	1.86	1.12	1.67	3.3	165	261	2.1	2.5	7	CT
121	.96	1.76	1.12	1.75	3.4	170	318	2.5	3.5	7	C
94(108)	.92	1.66	1.05	1.91	3.3	165	367	1.9	2.9	7	C
105	.85	1.46	.95	1.20	1.9	95	311	2.6	4.6	7	TC
81	.68	1.47	.85	1.47	1.5	75	240	.2	.6	7	CT
94	1.02	1.54	1.12	1.36	3.9	195	544	.8	1.0	8	CT
84	.77	1.52	.86	1.76	3.6	180	522	.2	.4	6	C
82	1.05	1.96	1.17	2.00	3.1	155	210	.8	.9	8	CT
98	.75	1.43	.84	1.10	2.3	115	401	1.1	2.5	7	CT
118	1.19	1.80	1.26	1.65	6.0	300	524	2.5	2.2	7	T
116	1.15	1.90	1.28	2.04	5.0	250	371	3.2	3.1	7	C
105	.79	1.33	.85	1.21	2.5	125	523	2.9	5.9	8	TC

APPENDIX II
Table 13

Haralson on Elsa Data.

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
108	.82	1.55	..94	1.46	2.1	105	287	4.7	8.9	7	CT
90	1.01	1.83	1.19	1.85	3.8	190	316	.9	1.1	8	TC
120	.98	1.58	1.08	1.32	4.3	215	555	6.1	8.1	9	T
114	.89	1.64	.98	1.20	2.8	140	323	3.4	5.5	9	CT
104(100)	1.10	1.68	1.14	1.66	5.0	250	537	3.8	4.0	7	T
84	.90	1.99	1.05	1.76	2.7	135	174	1.4	2.2	9	CT
125(25)	1.19	1.82	1.40	1.68	8.1	405	684	6.2	5.6	9	T
107	.85	1.51	1.04	1.48	3.0	150	444	.9	1.6	8	CT
119	.98	1.62	1.06	1.43	3.8	190	455	5.1	6.8	7	C
133	1.12	1.98	1.30	2.01	4.0	200	262	3.5	3.6	8	C
87	.87	1.76	.93	1.37	3.3	165	308	2.2	3.7	6	TC
110(61)	1.14	1.69	1.23	1.66	4.4	220	464	6.1	6.0	8	C
115	.97	1.91	1.06	1.56	3.2	160	234	2.4	3.2	7	TC
93	.64	1.18	.71	.88	1.0	50	310	.6	1.9	7	C
120	.99	1.48	1.15	1.38	3.6	180	566	2.1	2.7	8	T
92	.73	1.61	.89	1.39	1.9	95	232	1.1	2.6	7	CT
119	1.05	1.84	1.15	1.72	3.0	150	245	1.8	2.1	9	C
82	.62	1.46	.73	1.18	1.6	80	262	4.6	15.2	5	C
88(44)	.80	1.37	.92	1.13	2.1	105	416	2.5	5.0	9	C
105	.87	1.56	1.02	1.15	2.0	100	268	1.4	2.4	9	C

APPENDIX II
Table 14

Haralson on Osman Data.

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
131(30)	1.37	1.83	1.49	1.57	6.2	310	515	6.0	4.1	8	C
81	.66	1.18	.65	1.07	1.0	50	310	.4	1.2	8	CT
93(88)	1.06	1.49	1.08	1.45	3.2	160	493	2.7	3.1	7	CT
118	1.23	1.78	1.32	1.73	3.1	155	280	2.4	2.0	7	C
104	.76	1.38	.82	1.05	1.7	85	329	1.3	2.9	8	TC
121	1.19	1.75	1.28	1.74	4.9	245	466	3.2	2.9	8	T
132(25)	1.36	1.96	1.39	1.95	4.1	205	277	3.5	2.4	9	C
91(44)	.96	1.55	1.12	1.45	2.5	125	342	4.4	6.1	7	C
133(20)	1.27	1.87	1.38	1.88	6.5	325	506	.9	.7	8	C
136	.96	1.62	1.08	1.60	3.1	155	371	3.7	5.1	8	C
104	.75	1.21	.81	1.21	1.6	80	460	3.3	7.5	8	T
102	.85	1.43	.99	1.36	2.2	110	383	2.7	4.7	7	C
103	.95	1.66	1.00	1.37	1.9	95	211	.8	1.1	7	T
103	.87	1.40	.92	1.23	1.8	90	334	3.3	5.6	9	T
130	1.08	1.89	1.15	1.90	4.0	200	302	8.2	8.9	8	CT
112	.86	1.64	.98	1.49	3.0	150	346	1.7	2.9	7	CT
75	.56	1.21	.66	1.23	.8	40	230	.7	2.8	8	T
109	.72	1.46	1.83	1.36	1.8	90	295	1.3	3.2	8	T
72	.64	1.13	.73	.94	.9	45	318	.9	2.8	8	TC
103	.73	1.57	.86	1.22	1.8	90	237	.5	1.2	7	T

APPENDIX II
Table 15

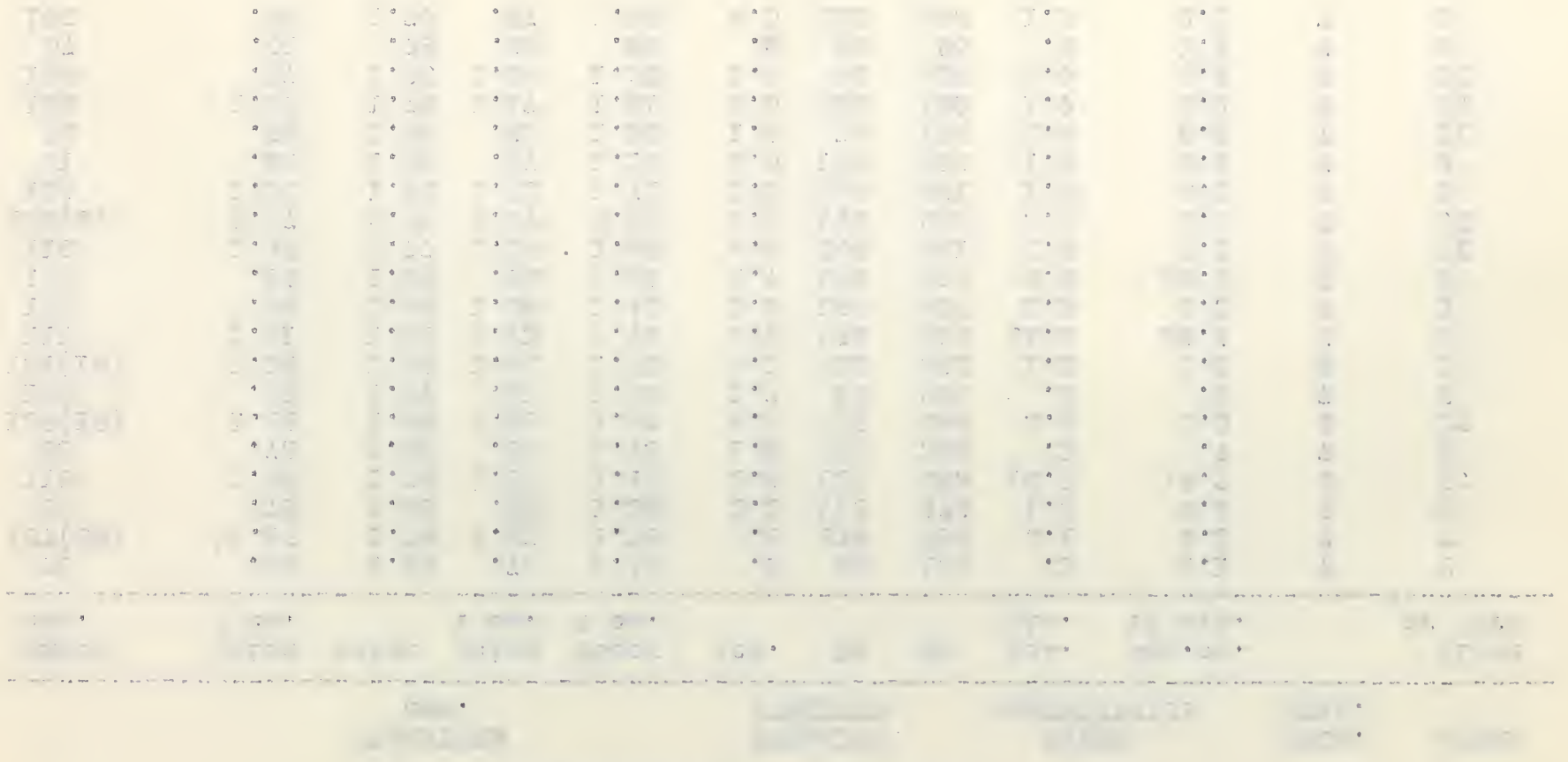
Haralson on Ornamental Data.

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
113	.93	1.68	1.15	.95	1.9	95	204	.7	1.0	6	CT
110	.95	1.39	1.11	1.21	2.5	125	474	4.7	6.6	7	C
85	.67	1.70	.79	1.87	.8	40	83	.4	1.1	5	C
138	1.11	1.67	1.25	1.70	4.7	235	514	7.4	7.6	8	T
112	.97	1.87	1.12	1.72	3.1	155	241	1.4	1.9	8	C
94	.82	1.55	.86	1.45	1.7	85	232	.3	.6	7	C
124	1.20	1.96	1.35	1.72	3.5	175	237	1.4	1.2	8	CT
115(10)	1.20	1.85	1.33	1.75	3.9	195	314	7.6	6.7	9	CT
89	.70	1.35	.95	1.13	1.1	55	228	.8	2.1	7	TC
100(10)	1.30	2.06	1.45	1.60	1.9	95	111	.2	.2	7	C
97	1.04	1.68	1.16	1.71	3.8	190	408	1.3	1.5	9	C
66	.70	1.47	.82	1.12	.9	45	144	.2	.5	6	CT
72(51)	.85	1.60	.95	1.62	1.7	85	211	.4	.7	6	C
101	1.24	2.00	1.37	1.70	4.0	200	255	1.1	.9	7	CT
90	.90	1.70	1.04	1.42	2.1	105	218	.3	.5	6	CT
93	1.23	1.93	1.33	1.58	5.4	270	383	1.1	.9	8	CT
80(10)	1.07	1.70	1.13	1.80	3.4	170	352	.6	.7	8	CT
94	.99	1.61	1.15	1.40	2.4	120	293	.3	.4	9	CT
101	1.00	1.70	1.07	1.48	3.0	150	311	.4	.5	7	CT
51	.54	1.09	.60	.98	.3	15	102	.1	.4	4	C

APPENDIX II
Table 16

Haralson on Beauty Data.

	DIAMETERS cms.				BREAKING STRENGTH			WATER CONDUCTIVITY		MACR. EVAL.	BREAK
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act.	BM	MR	Act. mls.	Squ.cm. 10 min.		Clean or Torn
78	.60	1.49	.70	1.32	.9	45	139	.3	1.1	7	T
107(25)	1.16	1.79	1.27	1.78	5.4	270	480	5.1	4.8	7	T
80	.79	1.35	.88	1.26	2.3	115	476	1.3	2.6	7	T
118	1.05	1.76	1.17	1.40	2.6	130	243	12.7	14.7	9	TC
93	.73	1.33	.80	1.43	1.8	90	390	.3	.7	7	T
138(15)	1.24	1.99	1.46	1.87	6.9	345	446	3.0	2.5	9	CT
105	.88	1.57	.91	1.59	1.7	85	224	.3	.5	7	T
131(10)	1.12	1.85	1.32	1.70	4.1	225	362	1.2	1.2	8	C
111	1.01	1.62	1.13	1.49	3.5	175	419	21.3	26.6	7	C
108	.99	1.69	1.08	1.43	3.2	160	338	2.3	2.5	6	C
108	.84	1.49	.92	1.24	2.7	135	416	5.8	10.5	7	T
118	1.09	1.77	1.19	1.68	4.8	240	441	2.3	2.5	9	CT
130(5)	1.07	2.00	1.27	2.00	3.9	195	248	3.5	3.9	7	CT
126	1.00	1.75	1.15	1.72	3.8	190	361	1.8	2.3	7	C
91	.82	1.28	.97	1.18	2.0	100	486	1.4	2.6	7	C
72	.68	1.60	.73	1.33	1.4	70	174	2.4	6.6	7	CT
138	1.09	1.75	1.17	1.81	4.5	225	428	1.9	2.0	8	TC
100	.97	1.62	1.00	1.35	1.9	95	228	4.0	5.4	7	CT
57	.61	.79	.68	.88	.8	40	83	.4	1.4	7	C
106	.89	1.70	.97	1.89	4.5	225	466	1.3	2.1	7	C



APPENDIX III
Table 1

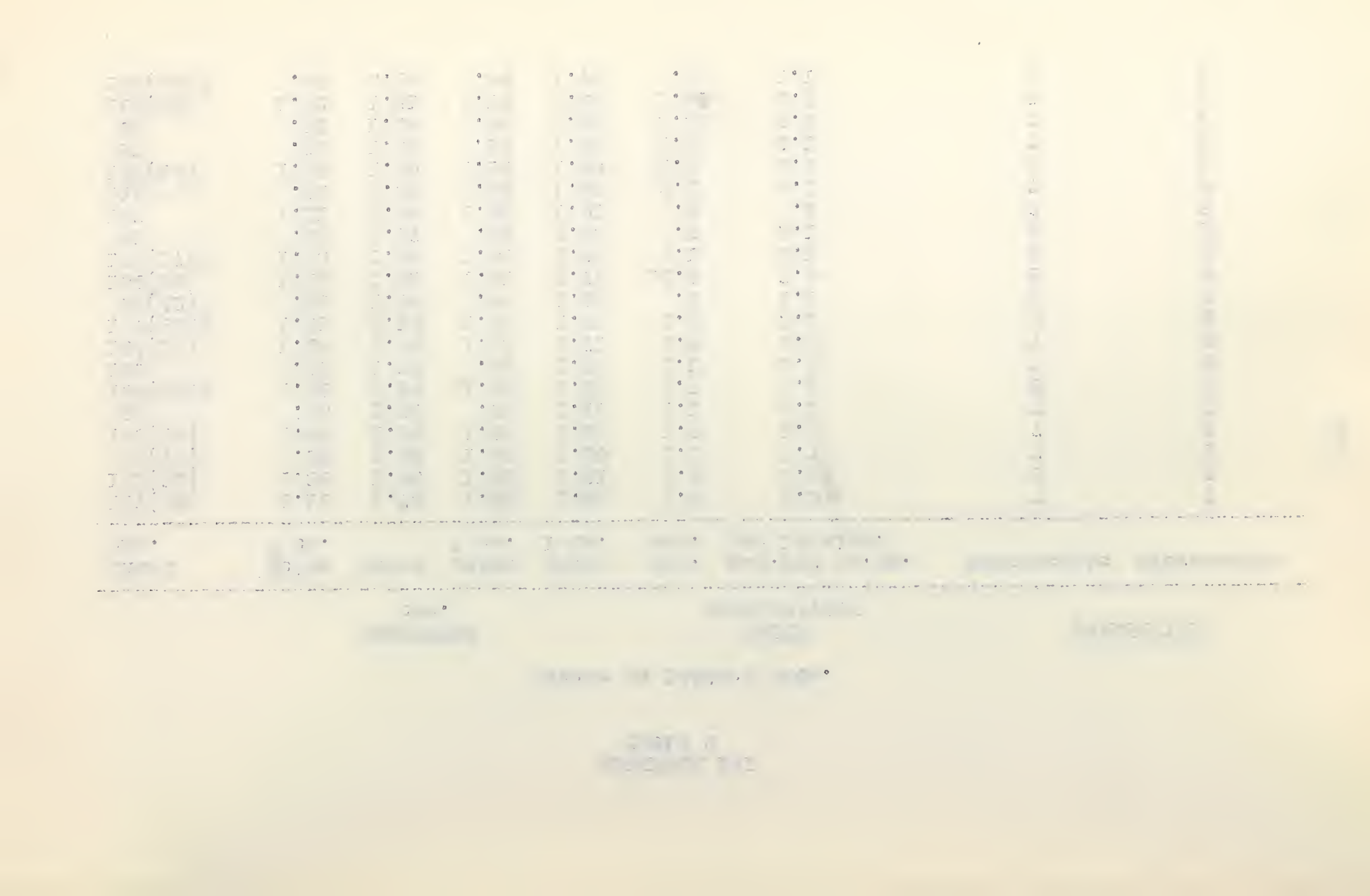
Rescue on Alberta Data.

Shoot cms.	DIAMETERS cms. Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	WATER CONDUCTIVITY Act. mls.	mls.per sq.cm. per 10 mins.	EVALUATION Macroscopic	Microscopic
126(10)	.96	1.63	1.12	1.45	1.6	2.2	8	7
133	1.05	1.80	1.23	1.80	2.6	3.0	9	7
90(15)	.70	1.88	.79	1.77	.6	1.6	8	4
104(372)	1.11	1.60	1.21	1.42	5.5	5.7	8	6
105(89)	1.02	1.65	1.14	1.39	2.4	2.9	8	5
111(87)	.92	1.88	.98	1.60	1.1	1.6	9	7
104(544)	1.23	1.63	1.35	1.60	7.3	6.1	9	8
102	.99	1.68	1.13	1.66	6.3	8.2	8	5
102(209)	1.18	1.67	1.35	1.67	8.4	7.7	9	7
49	.53	1.52	.64	1.27	.6	2.7	6	4
125	1.02	1.55	1.10	1.45	7.4	9.1	9	8
131(25)	1.07	1.79	1.16	1.46	.9	1.0	8	8
87	.80	1.46	.93	1.25	1.5	3.0	8	5
68	.64	1.47	.73	1.61	.4	1.2	7	7
132(30)	.93	1.80	1.10	1.74	4.4	6.5	9	9
146(15)	1.09	1.98	1.35	1.76	8.2	8.8	7	7
93	.60	1.13	1.66	1.07	1.2	4.2	6	8
150	1.08	1.82	1.37	1.73	2.2	2.4	7	7
157(25)	1.21	1.91	1.20	1.80	1.0	.9	8	5
101	.66	1.45	.75	1.26	1.6	4.7	8	5

APPENDIX III
Table 2

Rescue on Bedford Data.

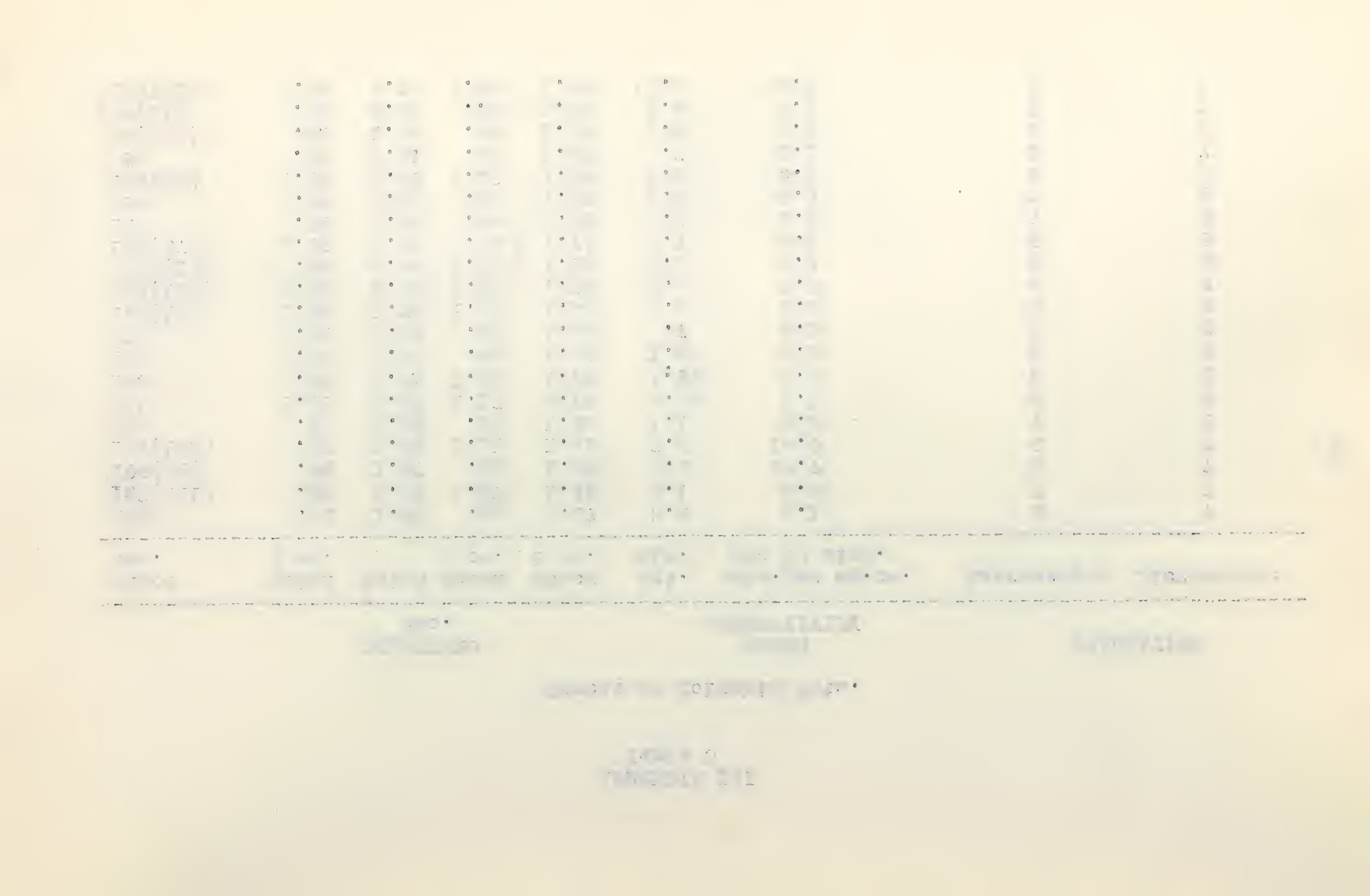
	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mls.per sq.cm. per 10 mins.	Macroscopic	Microscopic
127(45)	1.15	1.73	1.28	1.82	5.7	5.5	7	7
141(70)	1.38	1.82	1.62	1.61	5.4	3.6	8	6
98(15)	.95	1.56	1.26	1.50	1.1	1.7	7	9
145(15)	1.20	2.00	1.46	2.23	1.6	1.4	7	8
88	.75	1.72	.95	1.16	1.1	2.5	7	7
150(334)	1.54	2.14	1.82	1.89	6.7	3.6	9	6
109	.77	1.78	.95	2.05	1.1	2.4	7	8
124(30)	1.20	1.94	1.33	1.71	5.6	4.9	7	8
167(208)	1.51	2.19	1.80	1.78	5.5	3.1	9	8
98(42)	.84	1.64	.99	1.44	.6	1.1	8	7
154(25)	1.44	1.92	1.61	1.76	12.4	7.6	8	6
149(175)	1.33	1.88	1.52	1.64	7.1	5.1	9	8
88	.65	1.37	.82	1.43	.7	2.1	6	8
137	1.21	2.04	1.31	1.91	.5	.4	7	8
114	.82	1.30	.94	1.20	2.2	4.2	7	6
121(10)	1.00	1.50	1.12	1.30	2.0	2.5	8	8
87	.78	1.26	.99	1.22	2.9	6.1	7	6
95	.78	1.26	.90	1.09	3.3	6.9	7	4
119(25)	1.00	1.61	1.10	1.25	1.2	2.4	7	6
123(168)	.86	2.14	.95	1.74	.6	1.1	7	5



APPENDIX III
Table 3

Rescue on Columbia Data.

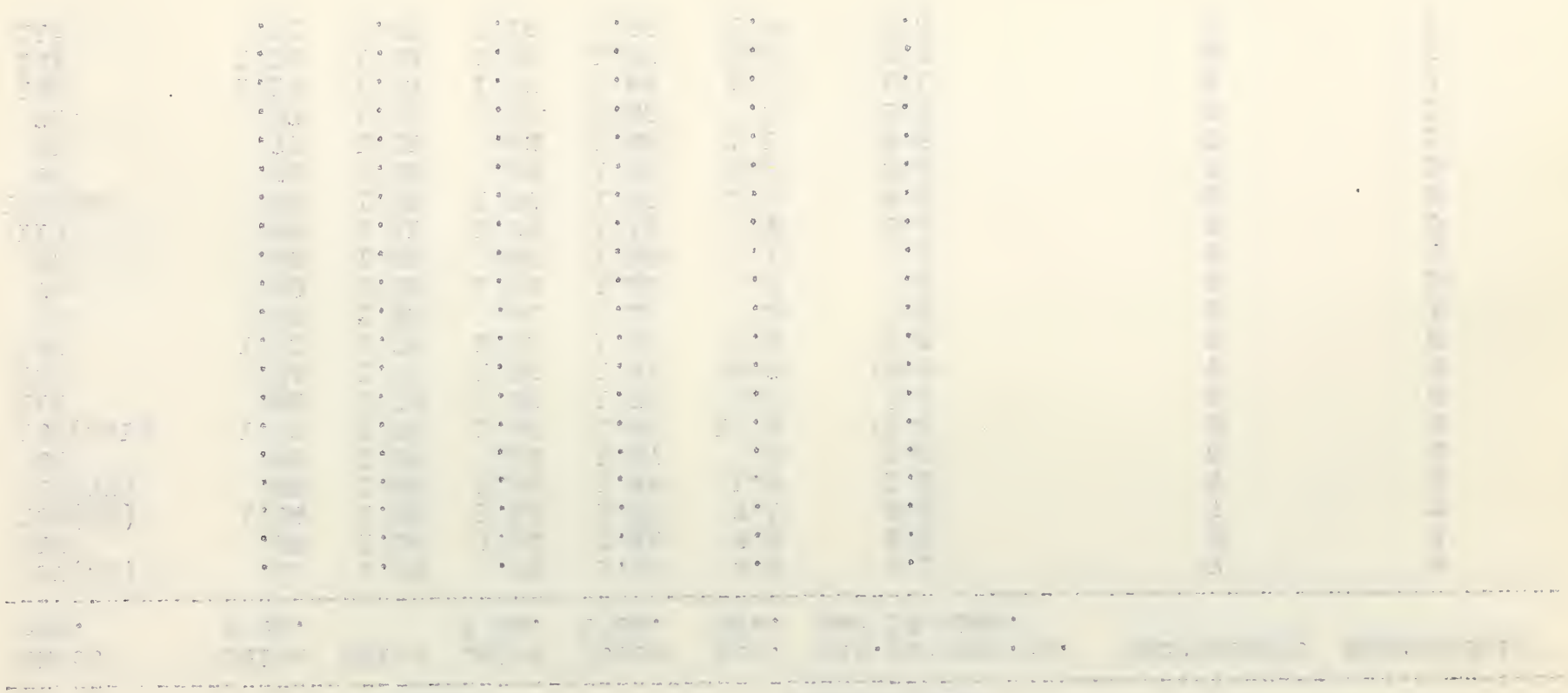
Shoot cms.	DIAMETERS cms. Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	WATER CONDUCTIVITY Act. mls.	mls.per sq.cm. per 10 mins.	EVALUATION Macroscopic	Microscopic
108	.82	1.29	.91	1.27	3.2	6.1	8	7
127(111)	.90	1.68	1.07	1.48	4.1	6.4	7	7
104(86)	.88	1.37	.85	1.30	6.5	10.7	8	7
104(133)	.97	1.62	1.11	1.45	7.4	10.0	8	7
90	.78	1.45	.88	1.31	1.1	2.3	7	4
141	1.16	1.94	1.17	2.18	3.3	3.1	8	6
103	.92	1.91	1.04	1.79	1.9	2.9	8	5
100	.88	1.90	.96	1.66	1.6	2.6	8	6
78	.62	1.18	.66	1.08	.7	2.3	7	7
135(10)	1.04	1.76	1.16	1.43	8.1	9.5	9	6
167(106)	1.46	2.08	1.65	1.75	3.4	2.0	9	7
100(10)	.90	1.46	1.00	1.38	3.6	5.7	8	6
134(27)	1.26	1.77	1.40	1.73	5.7	4.6	9	8
126	.92	1.68	1.05	1.32	3.6	5.4	7	5
84	.78	1.53	.90	1.50	1.9	4.0	7	8
124(94)	1.18	2.09	1.37	1.50	6.2	5.7	8	6
96	.90	1.41	.98	1.22	.7	1.1	8	7
86(105)	.93	1.46	.99	1.26	3.6	5.3	9	8
100(91)	.80	1.67	.86	1.55	4.4	8.7	7	7
137(30)	1.02	1.75	1.19	1.58	15.4	18.8	9	6



APPENDIX III
Table 4

Rescue on Dolgo Data.

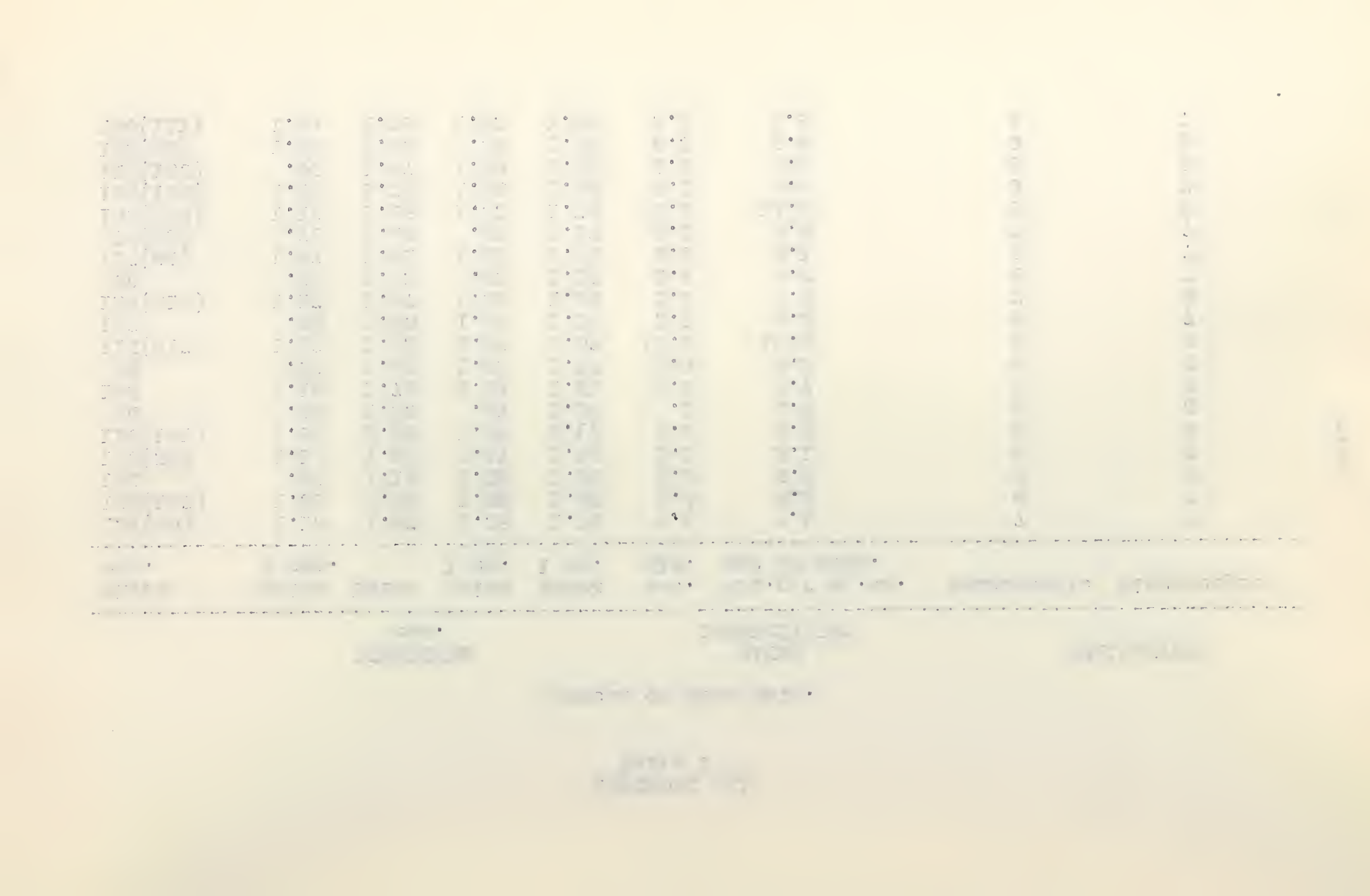
	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mls. per squ. cm. per 10 mins.	Macroscopic	Microscopic
87(38)	.81	1.45	.89	1.26	3.0	5.8	7	6
116	.97	1.50	1.10	1.42	6.5	8.8	9	7
138(25)	1.04	1.66	1.13	1.50	7.1	8.4	7	7
80(77)	.88	1.86	1.06	1.46	1.0	1.6	7	4
52	.68	1.57	.82	1.37	.5	1.5	8	5
126(341)	1.37	1.90	1.58	1.89	17.4	11.8	9	2
111	.82	1.75	.96	1.73	3.4	6.4	8	6
134	.94	1.55	1.06	1.45	8.7	12.5	9	9
136	1.23	1.77	1.43	1.50	1.9	1.6	9	6
55	.80	1.43	.91	1.31	.3	.6	6	4
76	.89	1.65	1.05	1.30	.5	.8	6	3
55	.69	1.35	.80	1.25	.1	.3	6	4
110	.88	1.41	1.04	1.41	.9	1.5	8	5
104(88)	.90	1.64	1.07	1.68	3.2	5.0	8	5
96	.72	1.23	.85	1.36	1.6	3.9	7	5
91	.73	1.31	.83	1.48	1.1	2.6	7	3
71	.57	1.44	.66	1.33	.3	1.2	5	5
104	1.10	1.83	1.27	1.64	1.0	1.1	7	7
121	1.12	1.50	1.09	1.37	3.2	3.2	8	6
110	.91	1.67	1.18	1.45	1.5	2.3	6	7



APPENDIX III
Table 5

Rescue on Elsa Data.

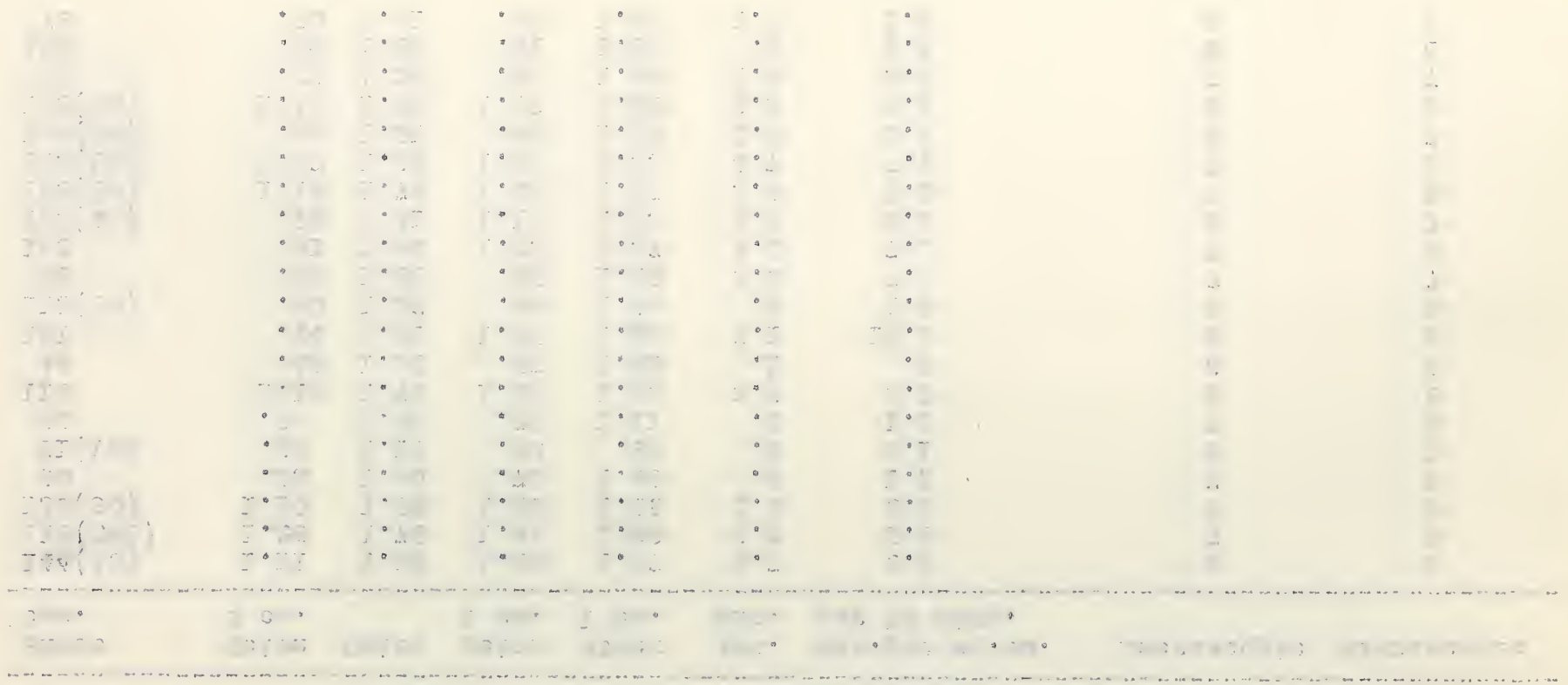
	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cms.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mls.per sq.cm. per 10 mins.	Macroscopic	Microscopic
134(40)	1.13	1.87	1.38	1.78	7.4	7.4	7	7
166(127)	1.36	2.20	1.53	1.80	3.4	2.3	8	7
196	.96	1.15	1.38	1.65	4.9	6.8	9	8
155(30)	1.15	1.85	1.37	1.72	2.2	2.1	8	7
159(191)	1.65	2.24	1.88	2.19	8.2	3.8	9	8
84	.68	1.35	.87	1.30	.9	2.5	6	6
143	1.18	1.76	1.34	1.61	9.5	8.7	9	8
90	.96	1.60	1.03	1.27	5.9	8.3	9	7
115(217)	1.17	1.83	1.27	1.57	11.2	10.4	8	6
107	.86	1.55	1.00	1.26	3.7	6.3	8	7
120(215)	1.17	1.97	1.30	1.69	3.9	3.6	7	5
96	.73	1.23	.83	1.27	2.4	5.7	8	7
117(64)	1.07	1.62	1.20	1.49	5.5	6.1	8	7
79(23)	.76	1.46	.87	1.17	2.5	5.5	7	7
103(246)	1.16	1.86	1.33	1.74	15.2	14.4	8	8
135(105)	1.10	1.78	1.42	1.68	4.2	4.4	9	7
115(125)	.96	1.87	1.00	1.62	4.2	5.8	8	8
153(50)	1.28	1.85	1.36	1.65	8.3	6.4	9	8
160(131)	1.40	2.20	1.63	1.78	3.0	1.9	9	7



APPENDIX III
Table 6

Rescue on Osman Data.

Shoot cms.	DIAMETERS cms. Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	WATER CONDUCTIVITY Act. mls.	mls.per sq.cm. per 10 mins.	EVALUATION Macroscopic	Microscopic
144(45)	1.11	1.85	1.26	1.57	5.7	5.9	8	6
118(228)	1.26	1.75	1.45	1.60	6.7	5.4	7	9
139(60)	1.10	1.58	1.29	1.45	5.5	5.8	8	8
60	.63	1.60	.70	1.44	.4	1.3	7	4
81(10)	.69	1.18	.82	.99	.8	2.1	8	7
66	.70	1.40	.76	1.11	.5	1.3	7	5
115	1.13	1.75	1.34	1.53	3.7	3.7	8	5
44	.48	1.32	.57	1.32	.1	.6	6	4
121	.94	1.51	1.05	1.30	7.1	10.3	8	6
113(40)	.80	1.37	.94	1.40	.8	1.6	8	6
98	.80	1.51	.95	1.28	3.5	7.0	7	7
123	.91	1.59	1.03	1.37	4.5	7.0	7	6
123(40)	.92	1.41	1.10	1.53	5.4	8.0	9	7
153(50)	1.16	1.74	1.28	1.57	3.4	3.2	8	8
123(10)	.87	1.64	1.00	1.33	4.7	7.9	7	5
105(94)	.86	1.51	.96	1.25	2.0	3.4	9	7
143(35)	1.10	1.55	1.17	1.26	6.3	6.6	9	6
67	.77	1.30	.86	1.05	1.6	3.4	7	7
105	.85	1.28	.91	1.26	.9	1.6	8	4
79	.70	1.11	.82	1.00	1.5	3.9	8	8



APPENDIX III
Table 7

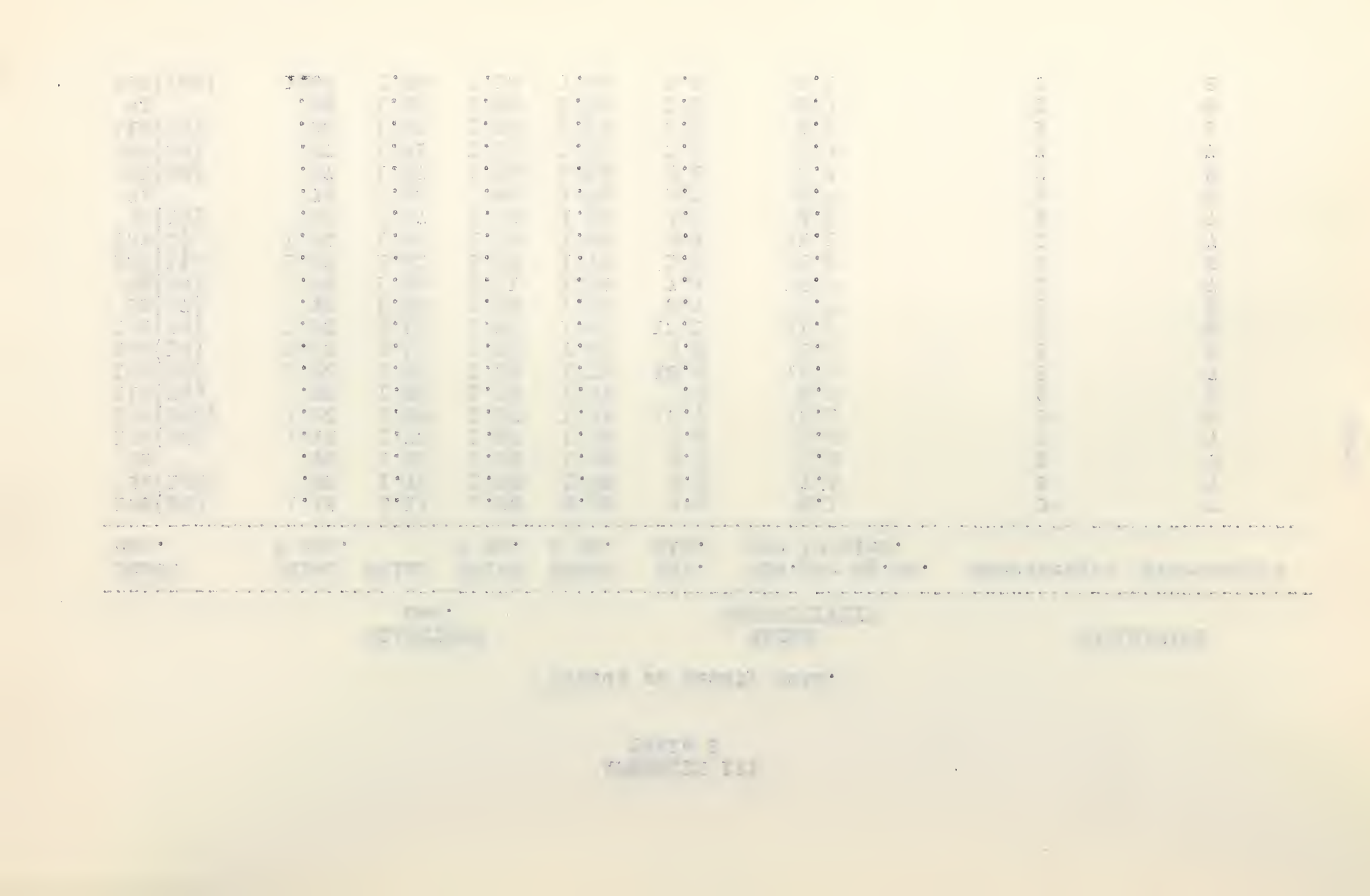
Rescue on Ornamental Data.

	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cms.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mls. per sq. cm. per 10 mins.	Macroscopic	Microscopic
85	.80	1.77	.90	1.00	.6	1.2	9	8
103(179)	1.20	1.64	1.25	1.43	3.9	3.4	7	8
147(104)	1.16	1.82	1.32	1.69	6.7	6.3	9	7
92	.85	1.51	.95	1.33	1.8	3.2	7	8
82(70)	.85	1.55	.90	1.68	2.1	3.7	9	8
142(58)	1.25	1.75	1.49	1.55	12.7	10.3	8	7
86(117)	.90	2.05	.93	1.62	2.9	4.6	8	6
141	1.04	1.70	1.09	1.50	4.3	5.1	7	6
143(50)	1.16	2.00	1.27	1.55	5.1	4.8	8	9
64	.78	1.47	.92	1.37	.5	1.0	7	6
66	.57	1.13	.69	.88	.9	3.5	7	8
139(58)	1.23	1.73	1.32	1.61	2.7	2.3	8	8
126(25)	.99	1.40	1.13	1.32	1.8	2.3	9	8
117(30)	1.00	1.57	1.17	1.27	4.4	5.6	7	8
113(50)	1.00	1.70	1.12	1.32	1.0	1.3	7	7
82(10)	.77	1.35	.96	1.36	.8	1.7	8	7
117	.97	1.61	1.17	1.53	6.7	9.1	7	8
133	1.25	1.63	1.28	1.50	2.6	2.1	8	6
92(25)	.88	1.45	.97	1.30	3.6	5.9	8	7
67	.68	1.21	.73	.94	.7	1.9	6	7

APPENDIX III
Table 8

Rescue on Beauty Data.

Shoot cms.	DIAMETERS cms. Scion 5 cms.	Union	Scion 1 cm.	Stock 1 cm.	WATER CONDUCTIVITY Act. mls.	mls.per sq.cm. per 10 mins.	EVALUATION Macroscopic	Microscopic
158(10)	1.44	2.14	1.60	2.00	3.4	2.1	9	7
94(122)	.82	1.70	1.00	1.50	3.9	7.4	9	7
86	.95	1.51	1.08	1.55	2.3	3.2	8	9
138(45)	1.12	1.73	1.27	1.56	5.2	5.3	9	7
130(253)	1.23	1.90	1.37	1.64	15.7	13.2	9	6
113(74)	.98	1.86	1.02	1.45	1.5	2.0	8	6
168(85)	1.23	1.82	1.36	1.78	12.2	10.2	8	7
146(10)	1.23	2.14	1.38	1.80	2.8	2.4	8	8
151(60)	1.23	2.12	1.38	1.60	13.1	11.0	8	6
88(57)	.91	1.55	1.09	1.28	3.7	5.7	8	8
92(50)	.93	1.52	1.11	1.44	7.4	10.9	9	7
136(115)	1.07	2.22	1.64	1.76	1.6	1.8	9	6
137(5)	1.04	1.96	1.20	1.60	9.4	11.1	8	7
90(15)	.88	1.57	1.26	1.28	4.0	6.6	9	7
75	.73	1.23	.80	1.06	2.7	6.5	9	8
81(50)	.87	1.87	1.05	1.14	2.2	3.7	7	8
80(34)	.87	1.81	1.12	1.53	3.5	5.9	7	7
113(45)	.93	1.48	1.05	1.19	6.1	6.6	9	9
93	.90	1.44	1.04	1.30	1.3	2.0	8	8
108(135)	1.00	1.59	1.13	1.40	5.0	6.4	9	8



APPENDIX III
Table 9

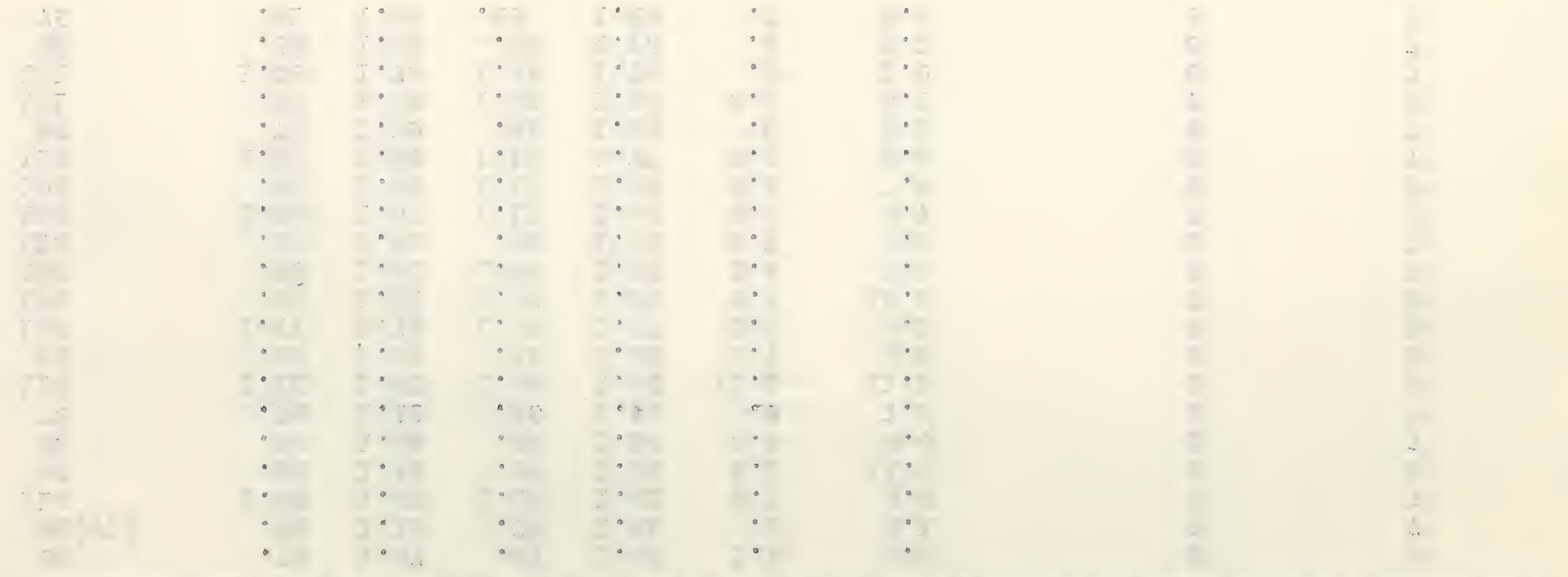
Haralson on Alberta Data.

Shoot cms.	DIAMETERS cms. Scion 5 cms.	Union	Scion 1 cm.	Stock 1 cm.	WATER CONDUCTIVITY Act. mls.	mls.per sq.cm. per 10 mins.	EVALUATION Macroscopic	Microscopic
112	.90	1.77	1.07	1.98	1.7	2.7	8	7
117	.90	1.49	.97	1.50	1.0	1.6	8	6
98	.92	1.62	1.00	1.41	.7	1.1	9	8
120	1.10	1.72	1.30	1.72	3.3	3.5	8	6
90	.72	1.35	.93	1.29	1.6	3.9	7	6
117	.96	1.44	1.15	1.38	.5	.7	7	8
76	.70	1.39	.80	1.33	3.6	9.0	5	6
116(120)	1.36	2.06	1.54	2.05	.9	.6	9	6
73	.70	1.48	.70	1.54	1.1	2.9	5	6
104	.80	1.44	.98	1.34	7.1	14.1	7	8
72	.64	1.55	.73	1.40	.6	1.9	7	6
83	.60	1.15	.70	1.22	1.7	6.0	9	8
115(165)	.92	1.64	1.38	1.69	2.5	3.8	7	7
75(48)	.66	1.27	.71	1.28	.3	.9	6	5
55	.39	1.04	.45	.90	.1	.8	5	7
75	.77	1.44	.86	1.17	.9	1.9	6	6
55	.55	1.08	.65	1.02	1.6	6.7	8	8
80	.78	1.46	.94	1.32	.4	.8	7	8
70	.68	1.46	.77	1.17	.1	.3	6	7
119	.92	1.55	.99	1.67	6.3	9.5	9	8

APPENDIX III
Table 10

Haralson on Bedford Data.

	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cms.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mls.per sq.cm. per 10 mins.	Macroscopic	Microscopic
98	.73	1.57	.87	1.44	1.5	3.6	8	8
58(71)	.55	1.16	.73	1.41	.5	2.1	7	7
114	1.08	1.49	1.10	1.22	8.7	9.5	6	7
96	.83	1.46	.95	1.20	6.3	11.6	8	8
93	.89	1.64	.95	1.34	3.4	5.5	8	7
73	.74	1.46	.85	1.45	.7	1.6	5	7
118	1.12	1.65	1.28	1.45	11.1	11.3	8	8
80	.63	1.39	.75	1.32	1.7	5.5	5	6
120	1.11	1.78	1.38	1.87	2.0	2.1	8	6
105	.98	1.51	1.07	1.26	9.5	12.6	7	8
108	.95	1.53	1.04	1.35	5.4	7.6	7	8
113	.87	1.61	.95	1.35	1.7	2.9	8	7
120	1.08	1.65	1.17	1.45	4.3	4.7	7	6
106	.95	1.64	1.14	1.49	5.6	7.9	9	9
113	1.00	1.88	1.18	1.77	5.2	6.6	7	7
80	.70	1.29	.85	1.35	.8	2.1	6	7
111	.90	1.59	1.06	1.35	3.9	6.1	7	8
121	1.08	1.73	1.35	1.74	.9	1.0	9	7
58	.55	1.18	.68	1.15	.5	2.1	6	7
75	.61	1.32	.69	1.23	.7	2.4	6	5



APPENDIX III
Table 11

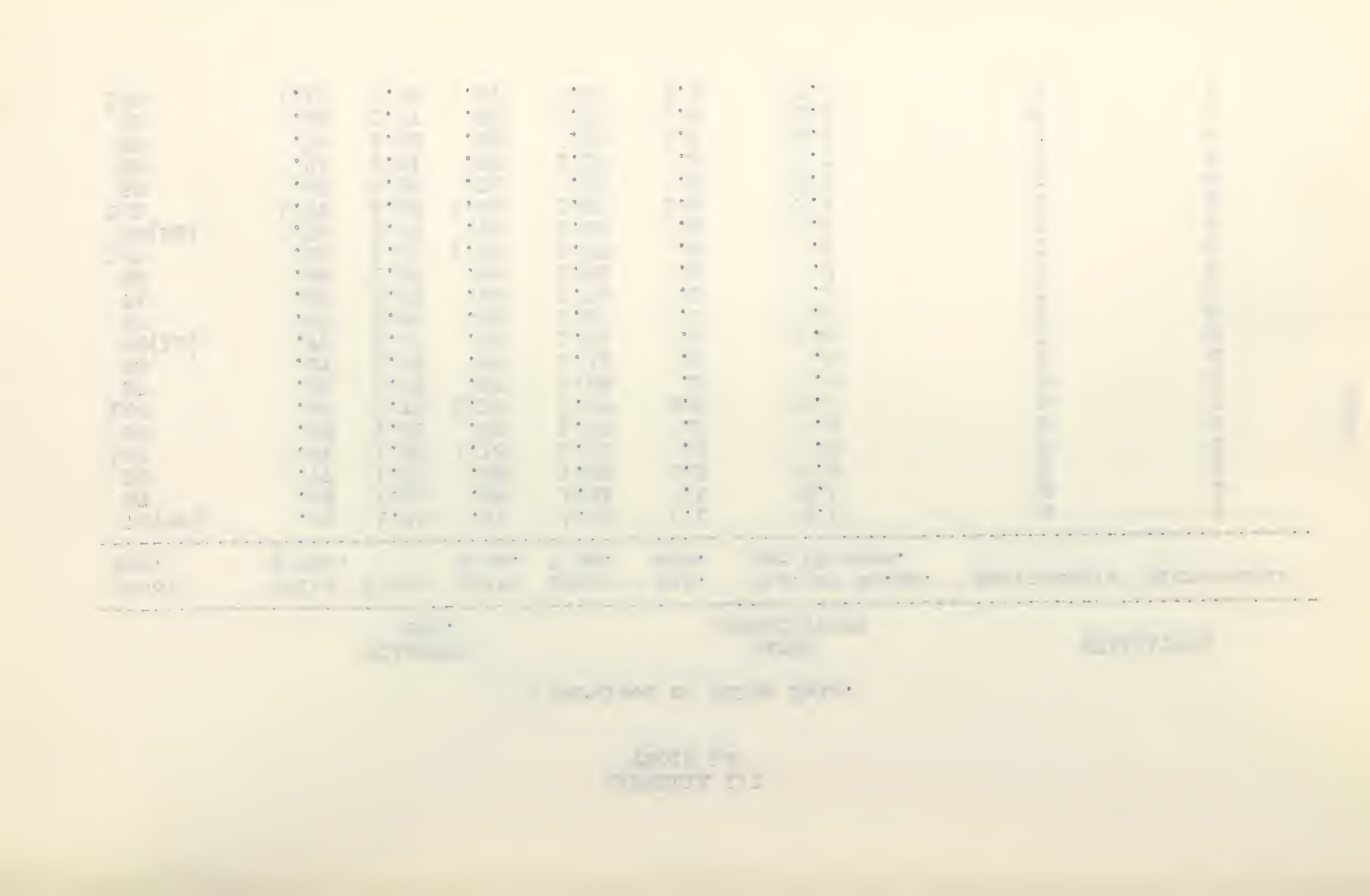
Haralson on Columbia Data.

	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mls.per sq.cm. per 10mins.	Macroscopic	Microscopic
126	1.10	1.62	1.26	1.49	2.0	2.1	9	7
123	1.02	1.90	1.24	1.96	1.0	1.2	9	7
102	.87	1.46	1.07	1.30	2.5	4.2	9	8
134	1.02	2.07	1.11	1.95	1.5	1.8	9	6
106(124)	.93	1.82	1.10	1.78	3.0	4.4	8	6
125	.98	1.58	1.05	1.58	5.5	7.3	8	6
45	.44	1.78	.52	1.72	.1	.3	5	3
88	.78	1.45	.84	1.42	1.7	3.2	5	4
128(10)	1.27	2.03	1.50	1.76	11.9	9.4	9	7
75	.60	1.30	.70	1.12	1.1	3.9	7	6
86	.73	1.35	.85	1.43	3.1	7.4	6	4
68	.62	1.05	.64	.89	.7	2.3	8	6
101	.83	1.70	.97	1.32	7.3	13.5	7	4
96	.86	1.64	.99	1.35	1.6	2.7	7	5
49	.45	1.08	.50	1.13	.8	5.0	5	6
132	1.10	1.62	1.22	1.72	7.6	8.0	8	5
126	1.08	1.91	1.19	1.77	2.6	2.8	9	6
41	.41	1.40	.52	1.47	.5	3.8	6	4
89	.77	1.33	.86	1.07	7.4	15.9	7	4
67	.59	1.31	.66	1.5	14.8	17.5	6	7

APPENDIX III
Table 12

Haralson on Dolgo Data.

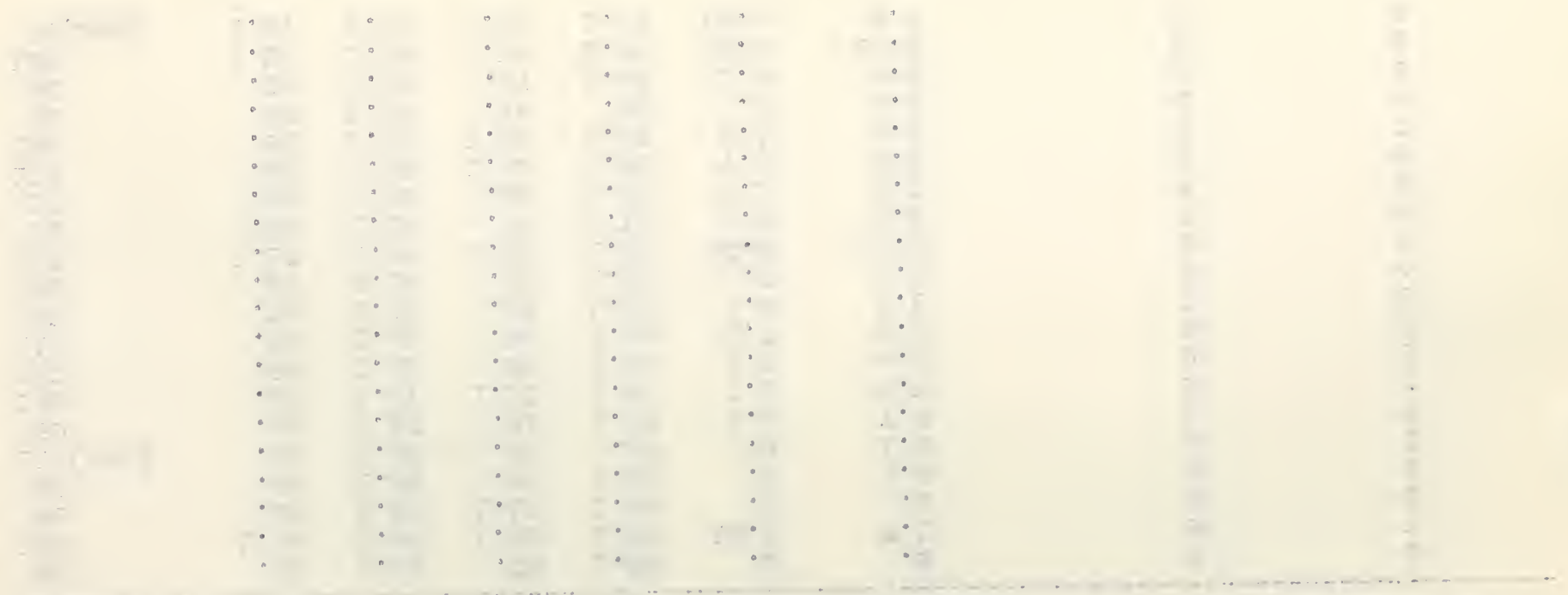
	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cms.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mls.per sq.cm. per 10 mins.	Macroscopic	Microscopic
75(98)	.81	1.49	.91	1.25	1.1	2.1	6	7
57	.49	1.19	.56	1.21	.4	2.1	6	5
80	.77	1.40	.95	1.29	2.3	4.9	8	8
107	1.01	1.65	1.13	1.51	.5	.6	6	5
85	.90	1.61	.98	1.49	.3	.5	6	5
124	.92	1.72	1.10	1.57	5.6	8.4	9	7
97	.84	1.69	.97	1.69	.3	.5	7	6
43	.57	1.38	.67	1.35	.2	.8	6	6
65(12)	.73	1.20	.80	1.04	.5	1.2	7	5
90	.85	1.50	.96	1.31	.5	.9	8	8
74	.88	1.63	.90	1.74	.2	.3	7	4
68	.54	1.26	.60	1.36	.2	.9	5	4
107	.93	1.87	1.09	2.07	.3	.4	7	7
80(98)	.78	1.50	.95	1.15	.3	.6	7	6
121	1.09	1.82	1.25	1.87	3.4	3.6	8	6
62	.65	1.32	.74	.95	.5	1.5	6	6
82	.74	1.61	.88	1.37	.3	.7	5	5
82	.74	1.32	.82	.97	1.4	3.3	7	6
95	.82	1.47	.92	1.40	1.5	2.8	7	6
109	1.13	1.80	1.27	1.57	2.9	2.9	9	5



APPENDIX III
Table 13

Haralson on Elsa Data.

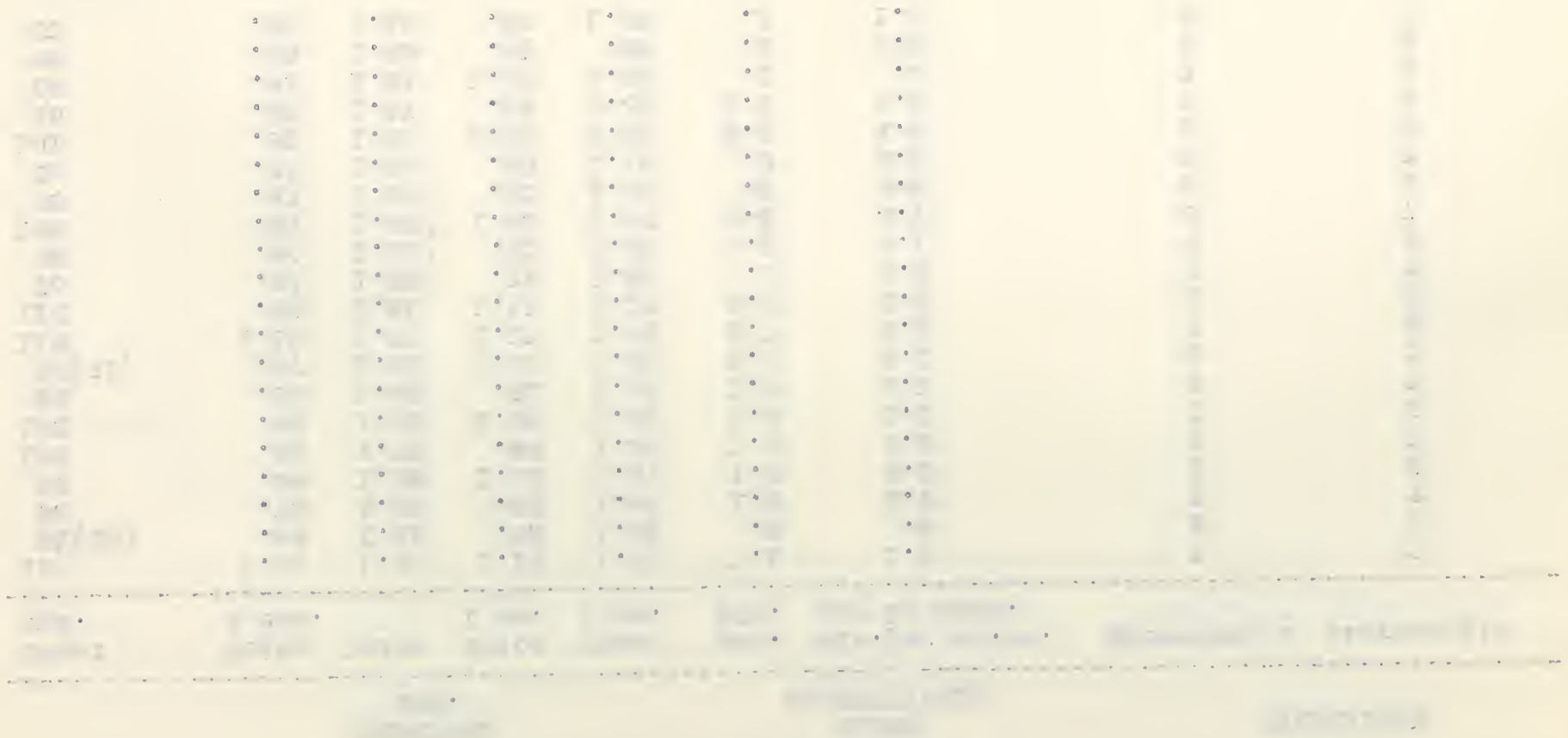
	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cms.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mls.per sq.cm. per 10 mins.	Macroscopic	Microscopic
60	.65	1.44	.70	1.54	.3	.9	8	6
140	1.34	2.05	1.42	1.95	10.0	7.1	9	7
88	.95	1.82	1.10	1.46	.3	.4	6	4
84	.68	1.35	.86	1.30	.9	2.5	6	4
110(103)	.86	1.96	.93	.86	.9	1.5	8	5
69	.62	1.17	.75	1.07	2.4	7.9	8	7
126	.94	1.61	1.10	1.36	7.4	10.7	9	7
127	.85	1.41	.92	1.23	3.7	6.5	9	6
112	.73	1.41	.85	1.04	2.7	6.5	9	6
107	.76	1.62	.84	1.38	3.2	7.1	7	6
88	.64	1.19	.75	1.12	.7	2.2	6	4
141	1.17	1.90	1.42	1.72	10.8	10.0	9	7
83	.60	1.26	.72	1.10	1.5	5.3	7	6
113	.83	1.42	.96	1.26	3.1	5.7	7	8
112	.98	1.58	1.13	1.58	7.5	9.9	6	8
109	.92	1.55	1.01	1.37	2.4	3.6	7	7
42	.36	1.00	.46	.92	.4	3.9	6	4
85	.78	1.52	.97	1.65	1.4	2.9	6	4
128	1.19	2.00	1.15	2.00	10.8	10.0	8	6
92(297)	1.24	2.01	1.32	1.87	10.0	8.3	9	6



APPENDIX III
Table 14

Haralson on Osman Data.

	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cms.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mls. per sq. cm. per 10 mins.	Macroscopic	Microscopic
110	1.01	1.90	1.18	1.63	1.1	1.4	7	7
81(39)	.64	1.64	.73	1.51	.2	.6	6	6
93	.73	1.66	.83	1.44	1.2	2.9	7	7
99	.96	1.52	1.03	1.37	1.8	2.5	8	6
108	.90	1.77	.90	1.38	1.4	2.2	7	7
123	.93	1.52	1.04	1.51	3.6	5.3	7	6
85	.64	1.20	.72	1.25	1.0	3.1	8	7
89(75)	.87	1.48	1.04	1.41	2.5	4.2	8	7
118	1.11	1.71	1.17	1.62	3.7	3.8	9	8
112	.96	1.61	1.11	1.37	6.0	8.0	9	8
73	.64	1.38	.75	1.23	.9	2.8	7	7
98	.84	1.51	.93	1.46	2.3	4.1	7	5
108	.94	1.47	1.03	1.47	2.6	3.7	9	7
55	.47	1.20	.53	1.02	.8	4.6	6	4
92	.76	1.50	.80	1.14	.9	2.0	7	7
101	.91	1.56	1.06	1.31	2.6	4.0	9	8
85	.80	1.47	.84	1.35	1.6	3.2	7	6
89	.93	1.84	1.00	1.62	.2	.3	7	6
70	.53	1.05	.61	.86	.4	1.8	7	6
57	.62	1.32	.66	1.06	.3	1.0	6	5



APPENDIX III
Table 15

Haralson on Ornamental Data.

	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cms.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mla.per sq.cm. per 10 mins.	Macroscopic	Microscopic
82	.77	1.50	.88	1.67	2.3	4.9	6	7
75	.57	1.34	.66	1.40	.9	3.5	6	7
104	.78	1.80	.89	1.88	1.1	2.3	7	7
74	.77	1.53	.73	1.60	.2	.4	6	4
106	.91	1.96	.96	1.90	2.8	4.3	6	5
91	.74	1.20	.87	1.50	2.0	4.7	7	6
71	.57	1.00	.60	.95	.7	2.7	7	6
90	.77	1.85	.88	1.55	.6	1.3	7	7
109	.96	1.89	1.10	1.56	1.1	1.5	8	6
115	.96	1.40	1.05	1.30	6.1	8.4	8	8
130	1.06	1.64	1.20	1.86	11.2	13.7	9	8
112	.96	1.75	1.08	1.55	5.6	7.7	7	7
98	.96	1.48	1.09	1.55	2.6	3.6	8	6
87	.89	1.47	1.00	1.02	1.7	2.7	6	5
71(58)	.82	1.44	.91	1.25	.2	.4	7	7
89	.87	1.60	.99	1.63	1.4	2.4	7	6
91	.93	1.68	1.03	1.59	.4	.6	8	7
78	.79	1.71	.94	1.59	.2	.4	7	7
86	.94	1.51	1.08	1.45	3.0	4.3	9	8
51	.73	1.55	.82	1.40	.4	1.0	8	7

APPENDIX III
Table 16

Haralson on Beauty Data.

	DIAMETERS cms.				WATER CONDUCTIVITY		EVALUATION	
Shoot cms.	Scion 5 cm.	Union	Scion 1 cm.	Stock 1 cm.	Act. mls.	mls.per sq.cm. per 10 mins.	Macroscopic	Microscopic
118	.93	1.69	1.02	1.55	.4	.6	7	8
91(63)	.88	1.46	.98	1.16	.9	1.5	9	6
127(86)	1.20	2.02	1.36	2.00	5.1	4.5	8	6
120	1.06	1.70	1.18	1.60	4.9	5.6	7	7
110	.80	1.40	.96	1.26	4.4	8.7	7	5
100	.91	1.52	1.00	1.28	2.5	3.8	7	7
130	1.13	1.90	1.22	2.12	3.6	3.6	8	7
86	.77	1.26	.85	1.13	1.9	4.1	8	7
121	.96	1.66	1.07	1.90	5.4	7.5	6	4
77	.55	1.32	.64	1.03	1.0	4.2	6	7
117	.96	1.66	1.10	1.87	3.4	4.7	7	7
148(96)	1.33	2.23	1.42	2.00	4.4	3.2	9	6
84(44)	.87	1.49	.91	1.19	6.1	10.3	9	6
118	1.00	1.67	1.05	1.67	.4	.5	9	9
116	.95	1.83	1.01	1.69	1.0	1.4	7	5
142	1.15	1.78	1.30	1.58	4.1	3.9	9	6
104	.94	1.46	1.00	1.34	.5	.7	7	4
106	.90	1.45	1.04	1.29	5.8	9.1	9	7
122	1.13	2.05	1.32	2.10	1.8	1.8	7	3
104	.86	1.49	.96	1.30	3.5	6.0	9	8

APPENDIX IV

The tables in this appendix report the water conductivity in ml.per squ. cm. of cross-sectional area for each union listed in Appendix II and two combinations listed in Appendix III. The area of the union was determined by using the mean of the sum of the diameters of the stock and scion 1cm, below and above the union.

Table 1 contains the conductivity rates for Tables 1 to 8 in Appendix II, Table 2 the rates for Tables 9 to 16 in Appendix II and Table 3 the rates for Tables 6 and 14 in Appendix III.

APPENDIX IV
Table 1

Water Conductivity
(in millilitres per square centimetre per ten minutes.)

Scion Variety - Rescue.

Rootstocks

Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Ornamental	Beauty
1.3	7.8	.4	6.7	7.7	4.4	3.5	1.3
1.8	6.0	2.7	19.0	3.1	1.3	2.5	5.5
2.2	2.8	4.5	1.9	2.6	2.5	3.0	6.2
5.2	1.7	2.5	5.8	.7	7.0	5.0	4.2
3.9	.4	2.7	4.0	3.8	3.0	4.3	5.7
1.6	1.3	3.3	2.5	6.8	1.2	5.8	2.5
1.1	3.7	5.3	4.3	1.2	4.8	3.4	1.3
2.4	6.9	3.2	2.6	.8	1.5	2.2	1.9
7.6	1.9	4.3	.8	4.7	9.2	3.9	3.4
3.5	1.9	4.0	2.5	2.2	4.8	5.3	3.5
.9	3.6	10.8	2.9	1.6	5.2	7.1	3.4
4.8	3.2	7.2	1.3	6.3	4.6	2.4	3.5
3.6	1.8	5.0	2.0	.8	2.1	2.2	1.2
3.6	2.6	6.1	2.6	8.0	8.6	2.6	5.0
1.8	6.6	4.3	2.2	8.3	3.9	1.4	3.2
5.9	2.0	3.2	2.2	4.9	4.4	2.6	2.4
1.0	6.7	2.4	2.6	3.5	1.8	5.0	1.2
2.2	8.1	6.0	5.4	2.1	2.0	3.6	2.1
2.2	5.7	3.4	.9	1.6	2.4	1.6	6.0
1.3	2.6	6.0	.8	3.0	1.5	1.3	1.5

APPENDIX IV
Table 2

Water Conductivity
(in millilitres per square centimetre per ten minutes.)

Scion Variety - Haralson

Rootstocks

Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Ornamental	Beauty
2.4	1.7	5.2	1.4	4.2	3.4	.8	.4
1.1	1.7	5.6	2.4	.5	.7	4.4	2.8
1.1	4.1	1.6	.1	5.4	2.2	.3	1.4
1.1	1.2	.2	2.1	3.6	1.3	4.4	9.7
.8	1.4	4.1	.6	2.7	1.9	.9	.3
5.1	2.1	1.7	4.1	.9	1.8	.3	1.4
.7	3.0	5.6	.6	3.3	1.6	.8	.2
3.8	4.2	8.2	.2	.8	3.4	4.1	.7
3.3	1.3	6.1	1.4	4.2	.4	.9	15.8
5.9	3.3	1.9	1.6	1.6	2.6	.1	1.9
.7	.9	5.9	1.1	2.1	4.1	.8	6.3
.2	2.3	.8	2.9	3.7	2.5	.3	1.4
1.1	1.2	1.4	.2	1.8	.8	.3	1.7
3.1	4.1	.8	.7	1.2	3.7	.6	1.1
.9	5.1	2.0	1.4	1.7	5.9	.3	1.6
3.2	4.3	.8	.4	1.1	1.4	.7	2.9
1.0	2.1	5.5	1.5	1.1	1.0	.9	1.1
3.1	4.0	2.6	1.5	6.2	.6	.2	3.7
2.1	2.2	12.0	1.5	3.0	1.7	.3	.8
2.8	5.2	.8	3.5	1.5	.6	.2	.8

APPENDIX IV

Table 3

Water Conductivity

(in millilitres per square centimetre per ten minutes)

Rescue on Osman	Haralson on Osman
3.7	.7
3.7	.2
3.7	1.2
.4	1.6
1.3	1.4
.7	2.8
2.3	1.3
.1	2.1
6.6	2.4
.7	5.0
3.6	1.2
4.0	2.1
4.0	2.1
2.1	1.7
4.4	1.2
1.9	2.4
5.5	1.7
2.2	1.5
.8	1.0
2.3	.5